

**Legend**

Water Wells

Anticlines

**WellStatus**

Active

Buried

Idle

New

Plugged

Cross Section

Study Area

1973-1974 Productive Boundary

Other Oilfield

6,0003,00006,000

Feet

**WZI INC.**  
BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

**SURFACE GEOLOGY MAP  
WITH ANTICLINAL STRUCTURES**

DATE: 10/17

FIGURE: 6.1-1

#### 6.1.1.4 Foxen Formation

The Foxen Formation, while it has not been mapped on the surface, is dark gray claystone of Pliocene age. In some areas it has minor interbedded sandstones. The Foxen is primarily claystone and appears only in the subsurface. The Foxen thickness across the study area ranges from 200 to 2,800 feet, (Worts & Thomasson, 1951). The porosity of the Foxen (based on core data) varies from 27% to 46% with permeability ranging from 5 to 0.8 millidarcy, ( $4.8 \times 10^{-6}$  to  $0.6 \times 10^{-6}$  cm/s), having an average permeability of 1.8 millidarcy, ( $1.5 \times 10^{-6}$  cm/s) in the silts and clays that provide the confinement. The core data is contained in **Appendix 4-1, Core Data and Well Histories** along with the tabulated values by well and zone. The Foxen claystone provides the upper confining element to the underlying Sisquoc Formation below the Upper Confining Layer across the entire Aquifer Exemption Expansion area.<sup>14</sup> The Foxen as a confining layer has been mapped where the upper confinement of the Upper Sisquoc claystone thins to the northeast on **Figure 6.1-2, Upper Sisquoc Confining Layer Isochore Map**. Trending to the north and east between the proposed aquifer exemption expansion boundaries and the study area boundary, the Foxen thins on the other side of the Sisquoc Valley and may be absent, (Worts & Thomasson, 1951).

#### 6.1.1.5 Sisquoc Formation

The Sisquoc Formation is of lower Pliocene/Miocene age and is one of the prominent producing formations in the Cat Canyon Oil Field. The Pliocene Sisquoc ranges from 1800 to 2500 feet thick and outcrops where the Howard Canyon crosses Gato Ridge, **Figure 4.1-2, Dibblee Surface Geologic Map**. The Sisquoc lies disconformably below the Foxen Formation. The Sisquoc Formation consists of interbedded sands and claystones. The Sisquoc has been divided for the purposes of the Aquifer Exemption Expansion into three main stratigraphic intervals and has been mapped as such in both maps and cross sections, the Upper Sisquoc interval, the S1b through the basal Sisquoc Formation below the Upper Confining Layer which are the production sands, and the Lower Sisquoc interval.

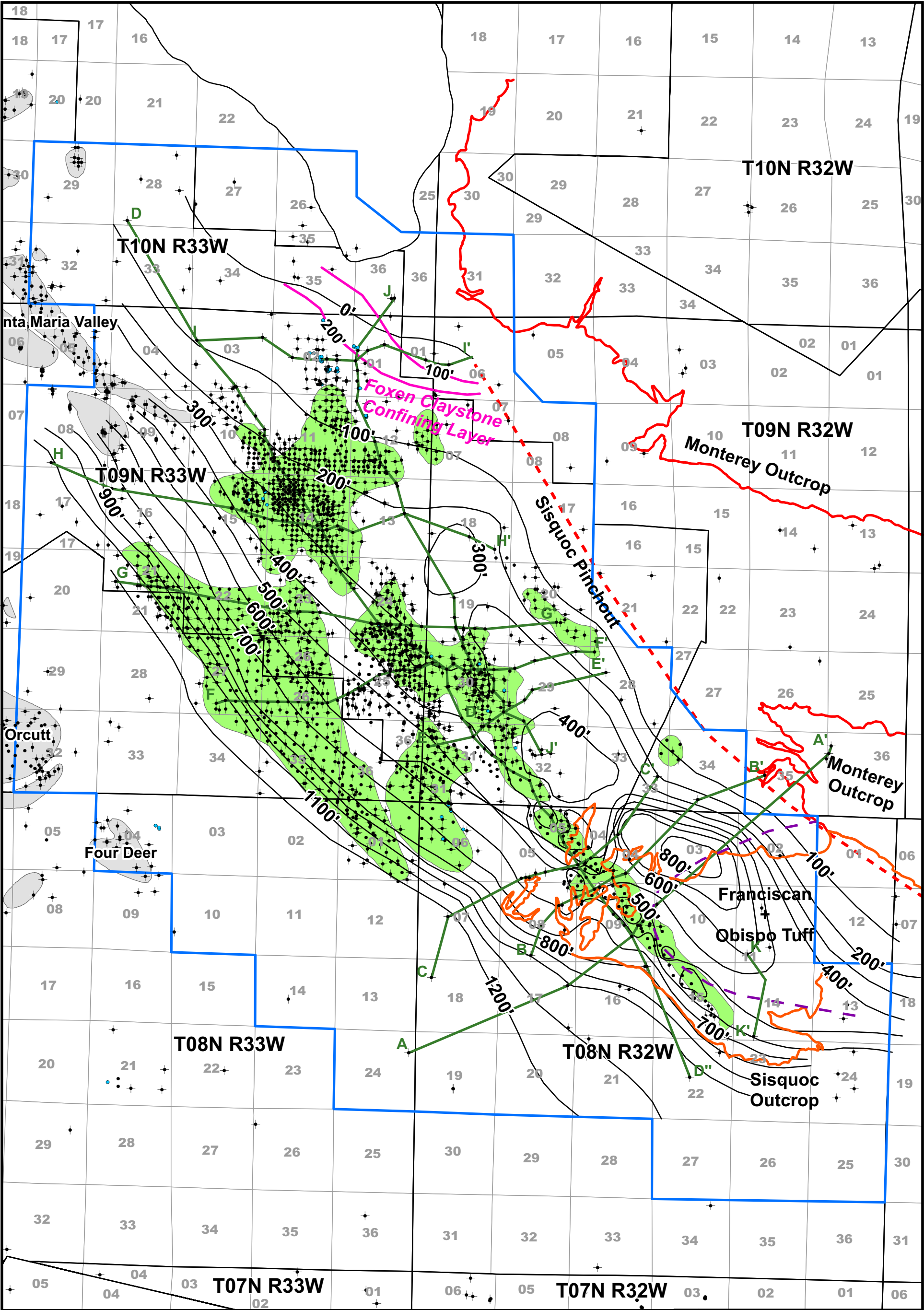
##### 6.1.1.5.1 Upper Sisquoc

The Upper Sisquoc interval has been mapped across the entire study area where present. It is a major claystone and provides the upper confinement of the productive Sisquoc Formation below the Upper Confining Layer below as shown in cross sections:

**Figure 4.1-3 Cross Section A-A';**  
**Figure 4.1-4 Cross Section B-B';**  
**Figure 4.1-5 Cross Section C-C';**  
**Figure 4.1-6a Cross Section D-D';**  
**Figure 4.1-6b Cross Section D'-D'';**  
**Figure 4.1-7 Cross Section E-E';**  
**Figure 4.1-8 Cross Section F-F';**  
**Figure 4.1-9 Cross Section G-G';**  
**Figure 4.1-10 Cross Section H-H';**  
**Figure 4.1-11 Cross Section I-I'; and**  
**Figure 4.1-12 Cross Section J-J'.**

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<sup>14</sup> The upper portion of the Sisquoc formation is primarily low permeability clays and also provides an areal extensive upper confining layer and has been determined to be the deepest of the upper confining layers.



**Legend**

**D3 Well Intersect**

**WellStatus**

- Active
- ✦ Buried
- ✦ Idle
- New
- ✦ Plugged
- Volcanics
- Sisquoc Outcrop

- Cross Sections
- Study Area
- Sisquoc Pinchout
- Foxen Clay Isochore
- Monterey Outcrop
- Upper Sisquoc Isochore Trace
- 1973-1974 Productive Boundary
- Other Oilfield

**WZI INC.**  
BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

UPPER SISQUOC  
CONFINING LAYER  
ISOCHORE MAP

DATE: 10/17

FIGURE: 6.1-2

**Figure 6.1-2, Upper Sisquoc Confining Layer Isochore Map** demonstrates the areal extent of this upper confining layer. The porosity of the Sisquoc claystone that comprises the Upper Sisquoc Confining Layer based on core data is varies from 27% to 42% with permeability ranging from less than 1 to 95 millidarcy, ( $8.4 \times 10^{-7}$  to  $8 \times 10^{-5}$  cm/s), having an average permeability of 15 millidarcy, ( $1.26 \times 10^{-5}$  cm/s) in the silts and clays that provide the confinement. The core data is contained in **Appendix 4-I, Core Data and Well Histories** along with the tabulated values by well and zone. This upper confining interval outcrops in the southern area of the study area.

A few of the water wells within the study area partially penetrate this confining layer just south of the Gato Ridge Area. **Figure 5.1-14, Cross Section K-K'** shows the relationship of these wells to the Alluvium and the underlying Upper Sisquoc Confining Layer. No water wells completely penetrate the Upper Sisquoc Confining Layer and none are hydraulically connected to the proposed aquifer exemption expansion intervals or formations.

There is no formation water or groundwater contamination found in the records. The groundwater and producing formation average values are show in Table 6.1-1. The regional average value of boron concentration in groundwater is at least one order of magnitude lower than the deeper Monterey and at least two orders of magnitude lower than that found in the Sisquoc Formation below the Upper Confining Layer; thus providing evidence of stratigraphic confinement of the producing intervals from the groundwater intervals. Each individual water well sample was reviewed in the context of covariance and none were found to show evidence of boron concentrations that would indicate communication. All data are contained in **Appendix 5-II** and **Appendix 5-IV**.

Table 6.1-1: Average Water TDS and Boron by Area and Formation(mg/L)				
Area	Formation		TDS	B
Sisquoc	All Sisquoc Data	Mean	9990	26
		Std. Dev.	8028	9
		Count	38	28
	Sisquoc: Post Steaming Production	Mean	5862	26
		Std. Dev.	2600	9
		Count	27	25
	Sisquoc: Native Formation	Mean	19862	34
		Std. Dev.	7558	17
		Count	12	4
	Monterey	Mean	10417	7
		Std. Dev.	6445	5
		Count	14	14
Central	Sisquoc	Mean	10745	28
		Std. Dev.	3815	20
		Count	14	11
	Monterey	Mean	12314	19
		Std. Dev.	6823	22
		Count	17	7
East	Monterey	Mean	10417	7
		Std. Dev.	6445	5
		Count	14	14
	Sisquoc	Mean	7668	12
		Std. Dev.	2547	12
		Count	17	9
West	Monterey	Mean	12314	19
		Std. Dev.	6823	22
		Count	17	7
	Sisquoc	Mean	22007	42
		Std. Dev.	5280	29
		Count	9	5
Gato Ridge	Monterey	Mean	9118	29
		Std. Dev.	1151	14
		Count	55	40
	Sisquoc	Mean	21000	
		Std. Dev.		
		Count	1	
	Sisquoc/ Monterey	Mean	6333	
		Std. Dev.	153	
		Count	3	

#### 6.1.1.5.2 Sisquoc S1b through basal Sisquoc Formation below the Upper Confining Layer

The Sisquoc producing intervals underlie the Upper Sisquoc Confining Layer. The sands are named the S1b through S9 or S10 with the basal sands being locally named throughout the field as the Brooks, the Thomas, and occasionally the Santa Margarita. They are Pliocene grading into Miocene in age and range in porosity from 25% to 63% with permeability as high as 3 darcy, ( $2.5 \times 10^{-3}$  cm/s). The low gravity oil, 12.5°API to 9°API, and the high oil saturations up to over 70% create an unusual California producing area with relatively low water cuts. The core data is contained in **Appendix 4-I, Core Data and Well Histories** along with the tabulated values by well and zone. In the West Area where the Sisquoc Formation below the Upper Confining Layer are deeper some of the wells have reported higher API gravities.

The Sisquoc productive sands S1b-S10, are aerially extensive across the Cat Canyon Oil field, however these sands pinch out or grade into low permeability silts and marine clays to the north east and to the west and south east. The extent of the sands are shown on **Figure 4.1-7a, Cross**

**Section D-D', Figure 4.1 -7b Cross Section D'-D'', and Figure 4.2-2 Top Sisquoc Structure Map, Figure 4.2-3, and Top of Sisquoc S1b Structure Map.**

**6.1.1.5.3 Lower Sisquoc Interval**

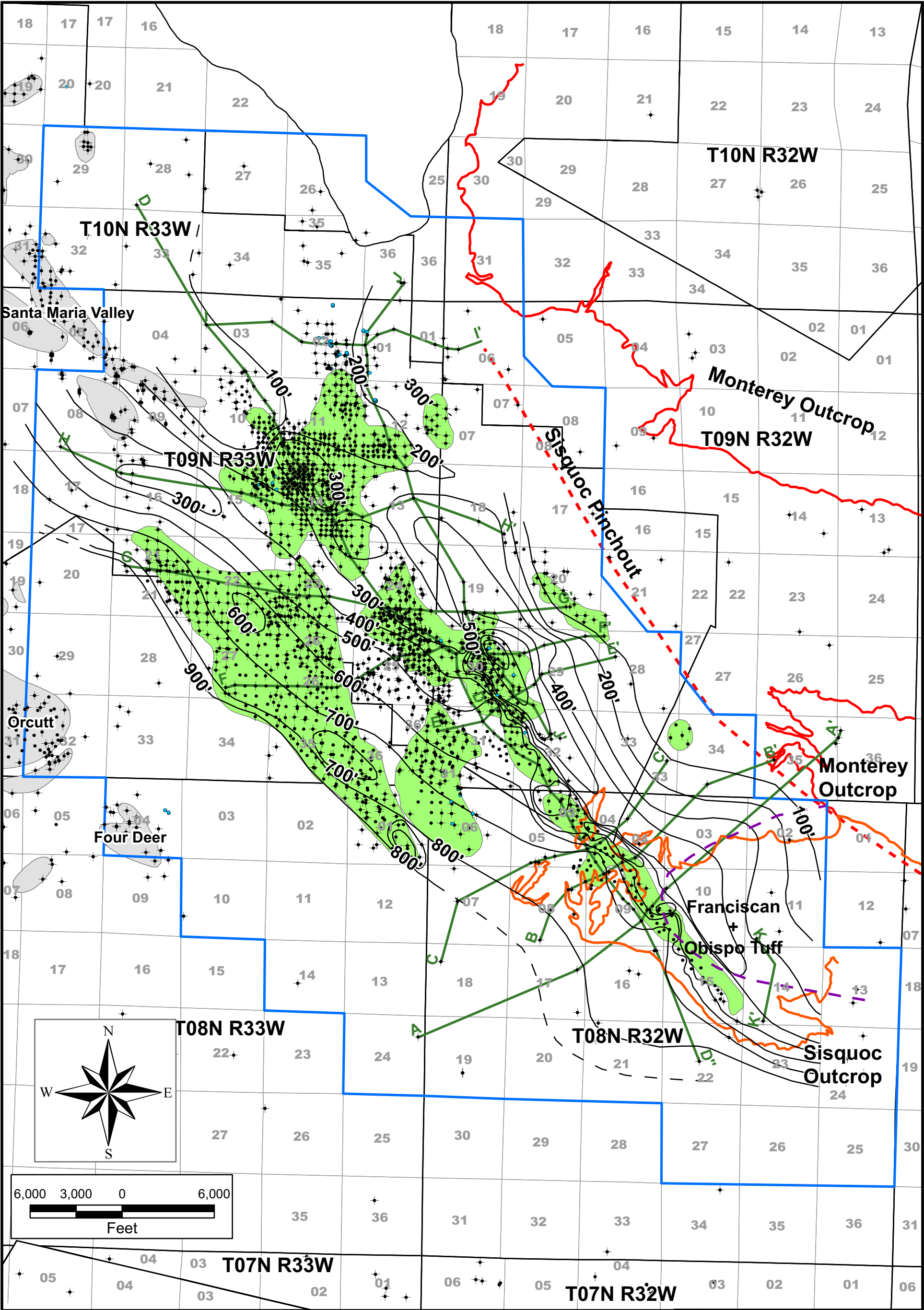
The marine claystone of Miocene age below the basal Sisquoc Formation below the Upper Confining Layer provides the vertical confinement of the production intervals of the basal Sisquoc Formation below the Upper Confining Layer and the Monterey Formation below. The Lower Sisquoc confining clay has permeability with a range from 100 to 0.03 millidarcy, ( $8.4 \times 10^{-5}$  to  $2.5 \times 10^{-8}$  cm/s) with the average being 11 millidarcy, ( $9.2 \times 10^{-6}$  cm/s). The core data is contained in **Appendix 4-I, Core Data and Well Histories** along with the tabulated values by well and zone. **Figure 6.1-3, Basal Sisquoc Confining Layer Isochore Map** delineates the areal extent of the basal confining layer in the study area as well as forming the lateral confinement of the basal Sisquoc Formation below the Upper Confining Layer including the Sisquoc Formation below the Upper Confining Layer locally called the Brooks, the Thomas and the Santa Margarita as shown in the cross sections.

**6.1.1.6 Monterey Formation**

The Monterey Formation of upper Miocene age in the Gato Ridge Area of the Cat Canyon Oil Field was identified as one of the most important naturally fractured reservoirs in the United States, (Hubbert & Willis, 1955). The Monterey consists of three distinct lithologic members and upper platy siliceous shale member, a middle fractured chert member and the lower limy shale member, (the Buff and Tan). In Cat Canyon Oil Field all three members were completed with about 60% of the production coming from the chert member. In the West Area the Monterey was sometimes named the Los Flores. The Monterey Formation ranges from zero where it sub crops on the basement complex to over 2500 feet over most of the study area. A maximum thickness of approximately 4000 feet occurs in the Olivera Area on the eastern edge of the study area. The Monterey chert zone has an estimated permeability of 10-15 darcy ( $8.4 \times 10^{-3}$  to  $1.26 \times 10^{-2}$  cm/s) with a maximum of 35 darcy ( $2.94 \times 10^{-2}$  cm/s) but an effective porosity of 6%, (Hubbert & Willis, 1955).<sup>15</sup> In the Cat Canyon Oil Field and surrounding oil fields, the Monterey Formation is thought to be both the source rock as well as the producing reservoir rock, (where it is naturally fractured). While core data has been taken in the Monterey, it is not considered representative of the total formation properties due to the natural fracturing, (Nelson, 2001). The data is included in **Appendix 4-I, Core Data and Well Histories** for completeness but is not utilized in the analysis. The permeability of the Monterey, where not naturally fractured, is that of a confinement layer. The areas of natural fracturing and of stratigraphic confinement (or limited fracturing) are defined by the areas of productive Monterey in the Cat Canyon Oil Field. These permeability barriers have been used in combination with the faulting to define the limits of the proposed aquifer exemption area and are discussed in more detail in Section 6.2, Hydrocarbon Production Potential.

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<sup>15</sup> The high permeability accounts for the Monterey's ability to produce large volumes of heavy oil.  
Aquifer Exemption Study  
2017  
Sisquoc and Monterey Formations  
Cat Canyon Oil Field



**Legend**

**D3 Well Intersect**

- Volcanics
- Approx. Lower Siskquoc Confining Layer Isochore
- Lower Siskquoc Confining Layer Isochore
- Siskquoc Outcrop
- Cross Sections
- Study Area
- Siskquoc Pinchout

**WellStatus**

- Active
- Buried
- Idle
- New
- Plugged

**WZI INC.**  
BAKERSFIELD, CALIFORNIA

**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

**BASAL SISQUOC CONFINING  
LAYER ISOCHORE MAP**

DATE: 10/17

FIGURE: 6.1-3

#### 6.1.1.7 Point Sal Formation

The Point Sal is an interbedded shale and sand formation of Miocene age. The upper portion of the Point Sal is a marine shale member of approximately 750 feet in thickness and provides the lower vertical confinement for the Monterey Formation. **Figure 4.1-1a through e, Type Logs (by Area)**, shows the Point Sal in its relationship to the Monterey. The permeability of the Point Sal is estimated as less than 1 millidarcy, ( $8.4 \times 10^{-7}$  cm/s), (Freeze & Cherry, 1979). Although most of the wells do not penetrate the Point Sal in the study area, a map was constructed utilizing the available data and is shown as **Figure 4.2-5, Top of Point Sal Structure Map**.

#### 6.1.2 Structure and Confinement

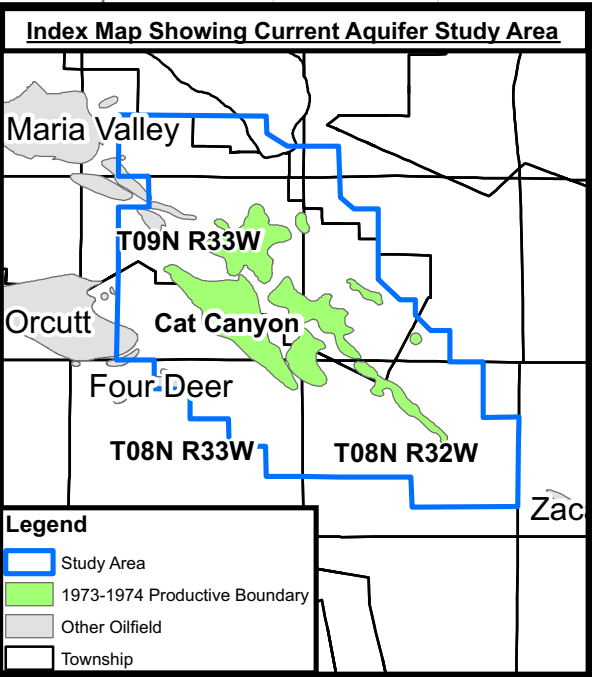
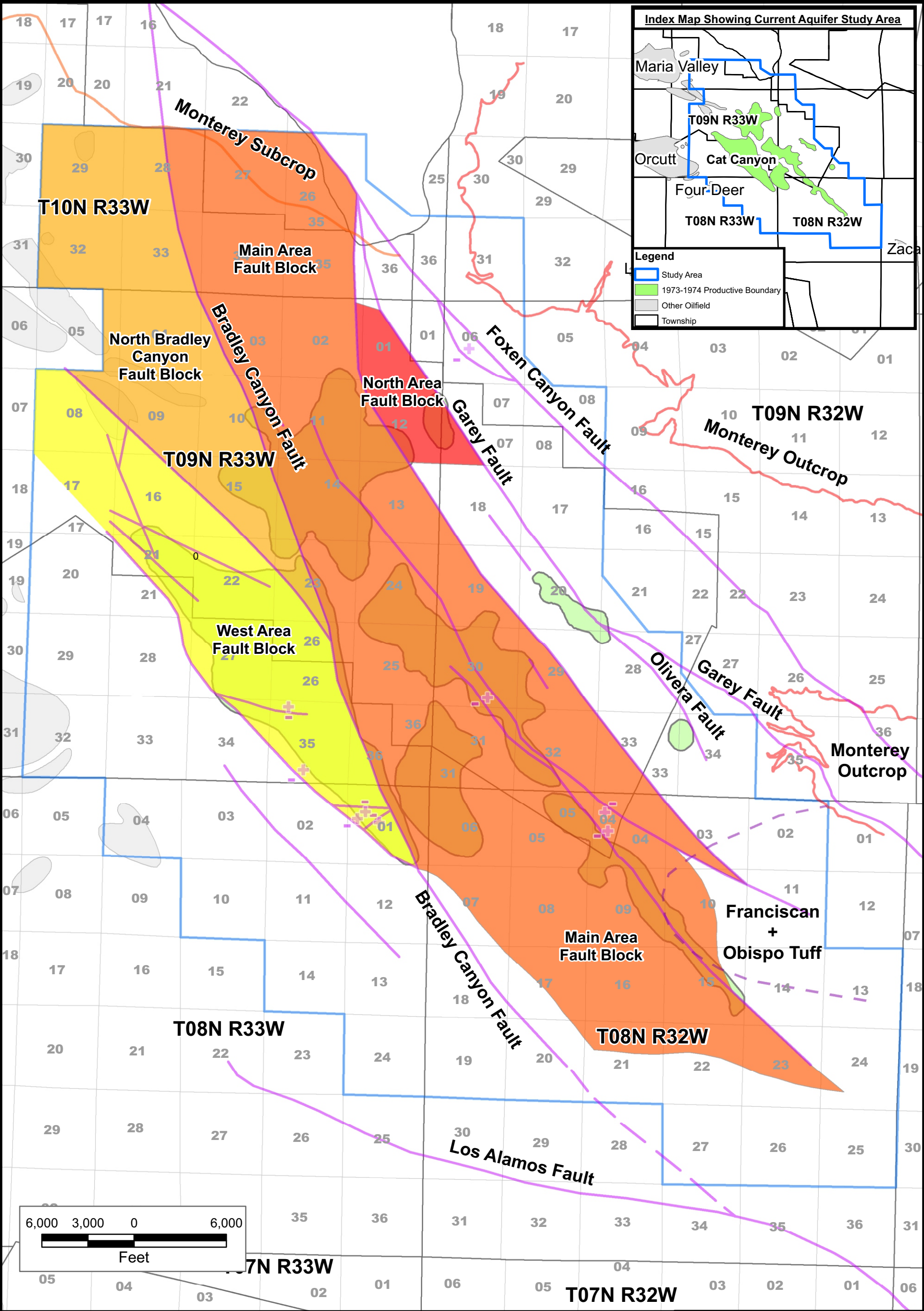
The structure of the Cat Canyon Oil Field is that of a homoclinal structure with superimposed anticlinal structures formed by late Miocene to early Pliocene strike slip movement of the steeply dipping faults related to the Santa Ynez regional fault system (Hickey, 1985) (Sylvester, 1979). These faults are sealing and have formed the traps for the accumulation of crude oil in the Sisquoc Formation below the Upper Confining Layer and for the producible crude oil from the Monterey in the form of coincidental fracturing along the en-echelon folding in proximity to the faults in addition to controlling the groundwater elevations and movement, (California Department of Water Resources (DWR), 2004). The structures are more pronounced in the Monterey than in the Sisquoc however, the major anticlinal/synclinal structures are easily discerned on the surface geology map, **Figure 6.1-1, Surface Geology Map with Anticlinal Structures**.

The named faults, from east to west as shown on **Figure 4.2-6, Fault Map** are related to the Santa Ynez fault system as discussed above in the Regional Structure Section 4.2 (Sylvester, 1979). They are called the Foxen Canyon Fault, the Garey Fault, and the Bradley Canyon Fault, **Figure 4.2-6, Fault Map**. These faults have had extensive lateral as well as vertical movement in the Miocene and Pliocene and have impacted the structuring of the local anticlines and sand deposition and are known to be sealing faults. The faults control commercial hydrocarbon accumulation in the Monterey Formation and Sisquoc Formation below the Upper Confining Layer as presented in Section 4 and shown on Cross Sections:

- Figure 4.1-3 Cross Section A-A';
- Figure 4.1-4 Cross Section B-B';
- Figure 4.1-5 Cross Section C-C';
- Figure 4.1-6 a Cross Section D-D';
- Figure 4.1-6 b Cross Section D'-D'';
- Figure 4.1-7 Cross Section E-E';
- Figure 4.1-8 Cross Section F-F';
- Figure 4.1-9 Cross Section G-G';
- Figure 4.1-10 Cross Section H-H';
- Figure 4.1-11 Cross Section I-I'; and
- Figure 4.1-12 Cross Section J-J'.

The Garey Fault, Olivera Fault, Bradley Canyon Fault and the Foxen Canyon Fault (or Santa Maria Valley Fault as it is sometimes called) are known to control groundwater levels as well, (California Department of Water Resources (DWR), 2004). As a result of the major sealing faults and other permeability barriers, four major fault blocks can be defined within the proposed Aquifer Exemption Study area. These fault blocks are shown on **Figure 6.1-4, Fault Block Areas** and are referred to for material balance purposes as follows:

- West Fault Block (contains a portion of the West Area and the Sisquoc Area);
- Central Fault Block (contains the Central Area, East Area, as well as portions of Gato Ridge Area, Sisquoc Area and West Area);
- Northwest Fault Block (contains a portion of the West Area and the Sisquoc Area); and
- Northeast Fault Block (contains a portion of the Sisquoc Area).



**Legend**

**Fault Throw**

- Down
- Up

Monterey Subcrop

Volcanics

Faults

Monterey Outcrop

- West Area Fault Block
- North East Fault Block
- N. Bradley Canyon Fault Block
- Main Area Fault Block
- Study Area
- 1973-1974 Productive Boundary
- Other Oilfield

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**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

**FAULT BLOCK AREAS**

DATE: 10/17      FIGURE: 6.1-4

### 6.1.2.1 Monterey

The Gato Ridge Anticline and the Los Flores/Cat Canyon Anticline are reflected at the surface in the marine Pliocene sediments and are mapped by Dibblee, **Figure 6.1-1, Surface Geology Map with Anticlinal Structures**. In the Gato Ridge Area there are two major faults to the east of the structure, **Figure 4.2-5, Monterey Structure Map**. The normal fault which is the most eastern fault is sealing to production also. It is sometimes referred to as the “Fugler Fault”. The un-named reverse fault which parallels the Gato Ridge Anticline has been demonstrated as sealing in the Monterey by elevated injection pressures and injection dye testing. Shut-in well pressures also add to the documentation. The other major faults in Cat Canyon Oil Field, i.e., Bradley, Garey, and Olivera, are demonstrated to be sealing by the pressure differences created by the oil and gas production activities along with some oil/water saturation differences or natural gas accumulation. **Figure 5.1-20, Monterey Formation Gradient Map with Pressures** highlights these sealing features. It should be noted that while the Monterey contains oil saturation throughout the study area, production and or injection is only possible where the structure creates natural fractures in the Monterey; the remainder is impermeable as shown by rapid pressure build up where voidage by production was not first created. The impermeable nature of the Monterey when not fractured is further demonstrated by the fact that one a Monterey injector is pressured up, the well maintains the pressure and does not decrease.

Those wells in Gato Ridge Area and the Central Fault Block with immediate high injection pressure (indicating no communication with the Monterey producing wells) are shown on the map. A dye test was conducted on the northern end of the Gato Ridge Area. It demonstrated communication within a one mile area on the south western side of the un-named sealing fault. Wells on the northeastern side of the same fault showed no communication in the dye test results even though they were closer to the injection well into which the dye was injected, **Appendix 6-III, Proof of Confinement**. The natural fracturing in the Monterey Formation appears to be more or less coextensive with the formation itself along the axes of major folding and faulting. Therefore the Monterey Formation production (where fractured) and the entrapment of the production (where fractured) reflect the same mechanisms as those found in a massive sand of the same areal extent and thickness, (Hubbert & Willis, 1955). The rapid communication within the Monterey and its response like that of highly permeable, massive sands makes the enhanced recovery technique of peripheral water flood effective. Where natural fracturing does not occur, the Monterey Formation has low permeability. This is evidenced by the fact that the Monterey Formation without the benefit of natural fracturing cannot commercially produce nor accept injection below the fracture pressure; thus, providing proof of lateral confinement in those areas without natural fracturing.

### 6.1.2.2 Sisquoc Formation below the Upper Confining Layer

In addition to the sealing faults discussed above, the structure on the southern end of Gato Ridge also provides confinement. The Gato Ridge anticline wraps the southern area with the Monterey and Point Sal being uplifted to the extent that the Upper Confining Layer of the Sisquoc out crops. Multiple tectonic uplift events influenced the deposition and areal distribution of the Sisquoc sands. At least one uplift event occurred prior to, and perhaps during, sand deposition since coarse grained sands appear to have accumulated in the low laying, near shore marine areas. Post sand deposition, relative sea level rise led to the deposition of the deep marine, fine grained confining layer above the Sisquoc sands. Subsequent uplift events placed the confining layer in an elevated structure at the southern end of the field. There are other unnamed

northwest-southeast trending faults that have also not been mapped as they are limited in areal extent. These faults can provide localized seals for the Sisquoc Formation below the Upper Confining Layer due to the lenticular nature of the Sisquoc Formation below the Upper Confining Layer and the movement of the faults providing a sand on clay seal.

## 6.2 Operational Confinement

The confinement of the injected fluids to the areas and intervals is documented by the pressure data collected in the normal course of business. The pressures were reviewed for Cat Canyon Oil Field over the course of multiple years and are due to depletion of the crude oil, produced water, and gas. The pressures demonstrate an inward gradient toward the producing wells which is created by the production activities, both extraction and injection, **Figure 5.1-19, Sisquoc Formation below the Upper Confining Layer Gradient Map with Pressures** and **Figure 5.1-20, Monterey Formation Gradient Map with Pressures**. The Material Balance calculations further substantiate the empirically derived inward gradient (from fluid level data) due to fluid depletion in the Cat Canyon Oil Field.

The gradient will continue to be toward the production wells. When production ceases the gradient will continue until the reservoir equalizes at which time the gradient will cease to exist.

Mass balance was assessed in several manners: Annual-Field Wide since 1977 (to compare to the cumulative net fluid voidage from inception of production), 2016 mass balance on an area wide basis by formations, and 2015 mass balance on a fault block basis. 2016 data were provided to incorporate the most recent complete year's data, however the data were inconsistent with the other years shown in Table 6.2-1.

**Table 6.2-1, Cat Canyon Oil Field, Field Wide Balance** shows the annual historic field wide mass balances based on DOGGR records back to 2005.

Table 6.2-1: Cat Canyon Oil Field Field Wide Balance since 1977				
Year	Oil (BBL)	Produced Water (BBL)	Injection (BBL)	Net (BBL)
2017	713,928	5,479,186	5,656,194	(536,920)
2016	1,185,347	8,063,539	9,349,369	100,483
2015	1,289,170	13,777,290	13,676,591	(1,389,869)
2014	1,579,585	17,664,106	17,914,396	(1,329,295)
2013	1,438,877	15,159,390	15,001,669	(1,596,598)
2012	839,883	12,607,366	12,223,548	(1,223,701)
2011	503,517	8,329,769	8,282,484	(550,802)
2010	336,451	4,415,922	4,445,305	(307,068)
2009	286,157	3,490,488	3,479,529	(297,116)
2008	230,676	3,129,773	3,122,441	(238,008)
2007	360,877	4,545,558	4,502,130	(404,305)
2006	354,202	4,322,425	4,255,820	(420,807)
2005	341,035	3,559,170	3,614,279	(285,926)
2004	386,543	5,156,080	4,771,291	(771,332)
2003	434,510	5,263,121	4,644,102	(1,053,529)
2002	412,539	5,484,397	5,533,211	(363,725)
2001	547,324	7,064,236	7,168,790	(442,770)
2000	550,114	6,492,561	6,657,787	(384,888)
1999	550,743	5,833,813	5,872,930	(511,626)
1998	843,920	7,336,727	7,472,720	(707,927)
1997	1,016,264	8,473,079	8,450,316	(1,039,027)
1996	866,969	8,898,763	7,145,223	(2,620,509)
1995	881,050	7,589,288	6,218,019	(2,252,319)
1994	1,070,524	9,269,593	6,664,442	(3,675,675)
1993	1,203,697	10,802,610	7,714,713	(4,291,594)
1992	1,054,829	10,326,382	7,998,858	(3,382,353)
1991	1,249,213	10,807,498	8,786,175	(3,270,536)
1990	1,309,702	11,962,574	10,087,094	(3,185,182)
1989	1,518,678	11,452,334	10,419,502	(2,551,510)
1988	2,436,009	14,750,859	16,269,230	(917,638)
1987	2,938,815	17,667,209	22,003,769	1,397,745
1986	3,528,739	18,972,508	19,333,982	(3,167,265)
1985	4,741,026	32,065,883	35,248,592	(1,558,317)
1984	4,986,256	31,090,336	34,046,819	(2,029,773)
1983	5,132,957	31,314,705	35,205,917	(1,241,745)
1982	5,127,121	29,468,777	36,205,222	1,609,324
1981	5,305,351	29,742,242	41,925,280	6,877,687
1980	5,760,918	31,322,564	37,866,547	783,065
1979	6,017,353	29,615,560	37,516,060	1,883,147
1978	6,315,995	26,692,968	30,383,521	(2,625,442)
1977	6,711,009	26,021,743	29,641,921	(3,090,831)

Table 6.2-2, 2016 Mass Balance by Area shows the 2016 mass balance by areas and formation. 2016 data appears to be confounded by a records problem.

Table 6.2-2: 2016 Mass Balance by Area				
Formation	Oil (BBL)	Produced Water (BBL)	Injection (BBL)	Net (BBL)
Central Area-2016				
Sisquoc	75,285	298,717	0	(374,002)
Area Wide	75,285	298,717	0	(374,002)
East Area-2016				
Monterey	16,014	85,561	0	(101,575)
Sisquoc	383,574	2,785,867	1,171,508	(1,997,933)
Area Wide	399,588	2,871,428	1,171,508	(2,099,508)
Gato Ridge Area-2016				
Monterey	76,435	1,304,365	1,304,366	(76,434)
Sisquoc	0	0	0	0
Area Wide	76,435	1,304,365	1,304,366	(76,434)
Olivera Canyon Area-2016				
Sisquoc	8,462	121,593	0	(130,055)
Area Wide	8,462	121,593	0	(130,055)
Sisquoc Area-2016				
Monterey	34,903	173,860	514,331	305,568
No Pool Breakdown	15,615	46,059	0	(61,674)
Sisquoc	498,518	626,489	729,033	(395,974)
Area Wide	549,036	846,408	1,243,364	(152,080)
Tinaquaic Area-2016				
Monterey	0	0	0	0
Sisquoc	0	0	0	0
Area Wide	0	0	0	0
West Area-2016				
Monterey	27,823	262,899	3,636,855	3,346,133
Sisquoc	48,718	2,358,129	1,993,276	(413,571)
Area Wide	76,541	2,621,028	5,630,131	2,932,562

Table 6.2-3, 2015 Mass Balance by Fault Block shows the mass balance results by formation and by fault block totals.

Table 6.2-3: 2015 Mass Balance by Fault Block						
Fault Block	AreaName	Pool Name	Oil (BBL)	Water (BBL)	Injected (BBL)	Net (BBL)
<b>Central Fault Block</b>						
Central Fault Block	Central Area	Sisquoc	106,419	335,886	0	(442,305)
Central Fault Block	East Area	Monterey	28,504	197,936		(226,440)
Central Fault Block	East Area	Sisquoc	391,539	5,347,956	1,233,024	(4,506,471)
Central Fault Block	Gato Ridge Area	Monterey	82,897	1,536,783	904,806	(714,874)
Central Fault Block	Gato Ridge Area	Sisquoc	346	18,883	650,924	631,695
Central Fault Block	Sisquoc Area	Monterey	11,937	85,064		(97,001)
Central Fault Block	Sisquoc Area	No Pool Breakdown	13,161	78,530	0	(91,691)
Central Fault Block	Sisquoc Area	Sisquoc	369,524	281,471	547,472	(103,523)
Central Fault Block	West Area	Monterey			3,861,905	3,861,905
Central Fault Block	West Area	Sisquoc	7,029	3,969		(10,998)
Fault Block Total			1,011,356	7,886,478	7,198,131	(1,699,703)
<b>NE Fault Block</b>						
NE Fault Block	Sisquoc Area	Sisquoc	0	0		0
<b>NW Fault Block</b>						
NW Fault Block	Sisquoc Area	Monterey	10,520	52,773	746,282	682,989
NW Fault Block	Sisquoc Area	No Pool Breakdown	14,370	48,823	0	(63,193)
NW Fault Block	Sisquoc Area	Sisquoc	106,735	254,285	0	(361,020)
NW Fault Block	West Area	Monterey	0	0	0	0
NW Fault Block	West Area	Sisquoc	0	0	0	0
Fault Block Total			131,625	355,881	746,282	258,776
<b>West Fault Block</b>						
West Fault Block	Sisquoc Area	Monterey	3,620	189,974		(193,594)
West Fault Block	West Area	Monterey	40,550	1,067,842	1,773,754	665,362
West Fault Block	West Area	Sisquoc	84,004	4,009,722	3,729,453	(364,273)
Fault Block Total			128,174	5,267,538	5,503,207	107,495
Field Wide			1,271,155	13,509,897	13,447,620	(1,333,432)

The Conservation Committee of California Oil and Gas Producers (CCCOGP) records were utilized to establish and analyze the pre-1977 production and injection characteristics of the field. During the early production years at Cat Canyon the primary production target was the Monterey Formation. During this period there was limited reinjection into the field formations. Later at the direction of the predecessor to the current Regional Water Quality Control Boards surface disposition of produced water from Cat Canyon Oil Field ceased and by 1985 water production and injection were balanced on a yearly basis, leaving a large cumulative fluid voidage in the Monterey. The chart below shows the production and injection history.

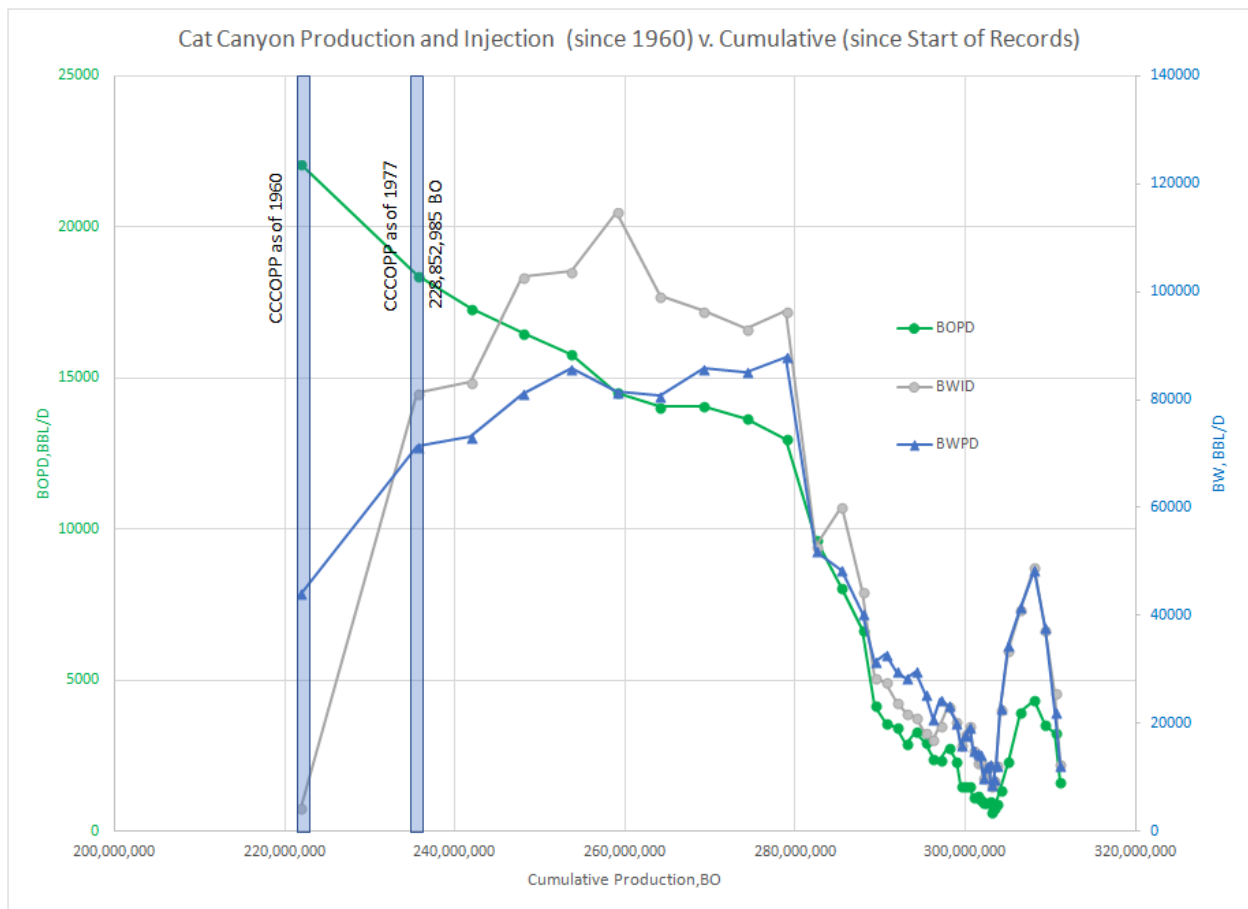


Figure 6.2-1

The calculated voidage for the field as a function of the cumulative production (based on material balance) is plotted in the following chart.

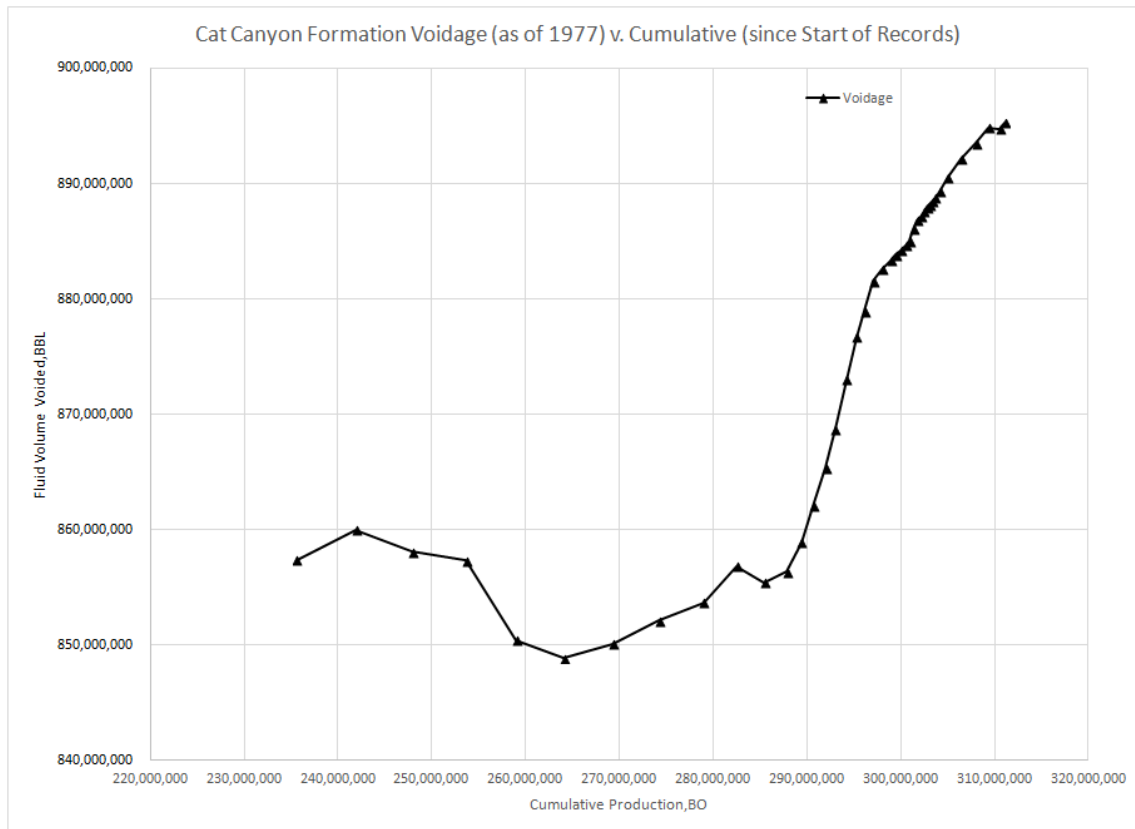


Figure 6.2-2

The current trend for utilization of produced water indicates that the total voidage created by historic fluid management activity will increase since oil is being sold and no water is being imported into Cat Canyon Oil Field. This material balance conservatively utilized fluid withdrawal only; the volume associated with the produced gas (which is significant) was discounted. The fluid level data and the production and injection data utilized in the analyses are included in **Appendix 5-V, Fluid Level and Material Balance**.

Presently, depending on the fault blocks in the designated areas, the Sisquoc Formation below the Upper Confining Layer are the primary production target and the deeper Monterey Formation is the target for reinjection of produced water not being used for steam or water flooding. The gradient will continue to be toward the production wells. When production ceases the gradient will continue in the same direction until the reservoir equalizes at which time the gradient will cease to exist.

### 6.3 Hydrocarbon Production/Potential

The Sisquoc, basal Sisquoc Formation below the Upper Confining Layer, (Brooks, Thomas, and Santa Margarita) and Monterey Formations are hydrocarbon bearing and commercial oil production is accomplished using primary and enhanced production (steam and water flood methods). The crude oil ranges from 8° API to over 20° API gravity; steam and water reinjection is an essential part of the commercial production process. **Figure 6.3-1, Cat Canyon Oil Field Oil Production and Injection History** shows the oil production history for the Cat Canyon Oil Field.

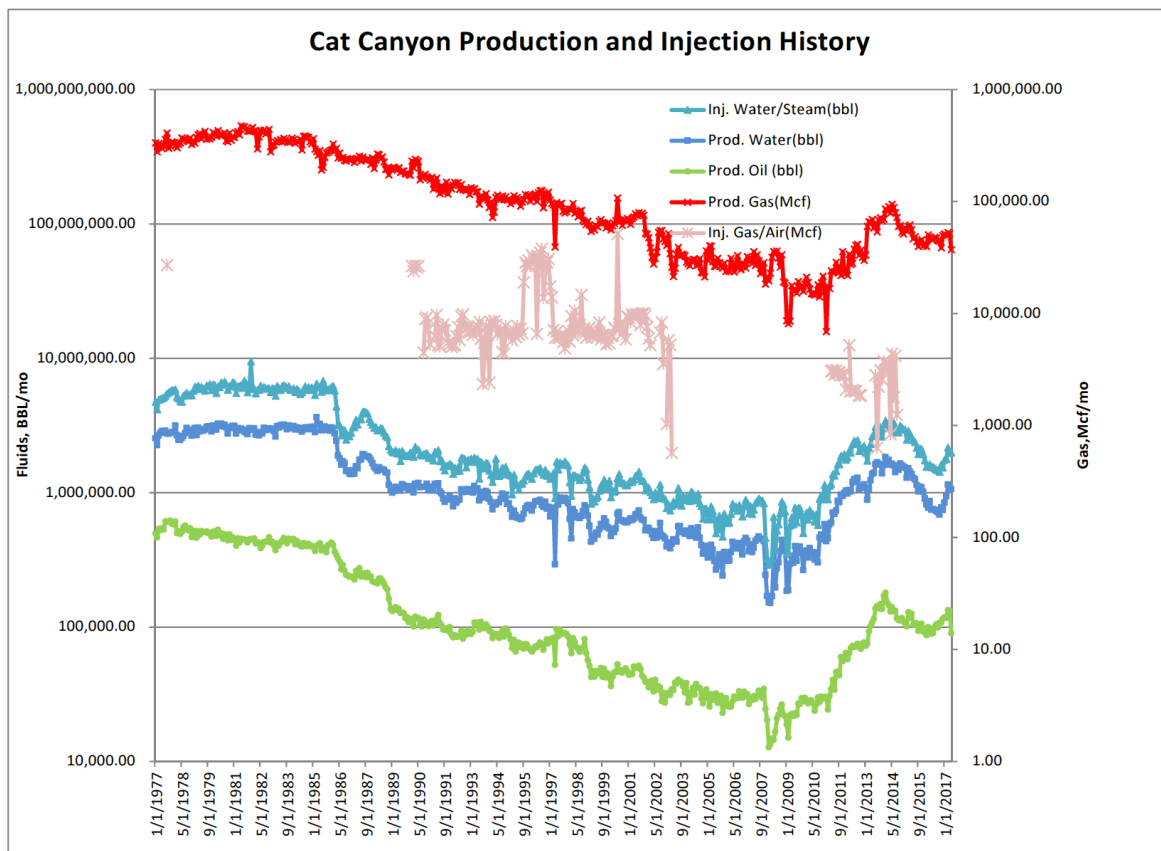
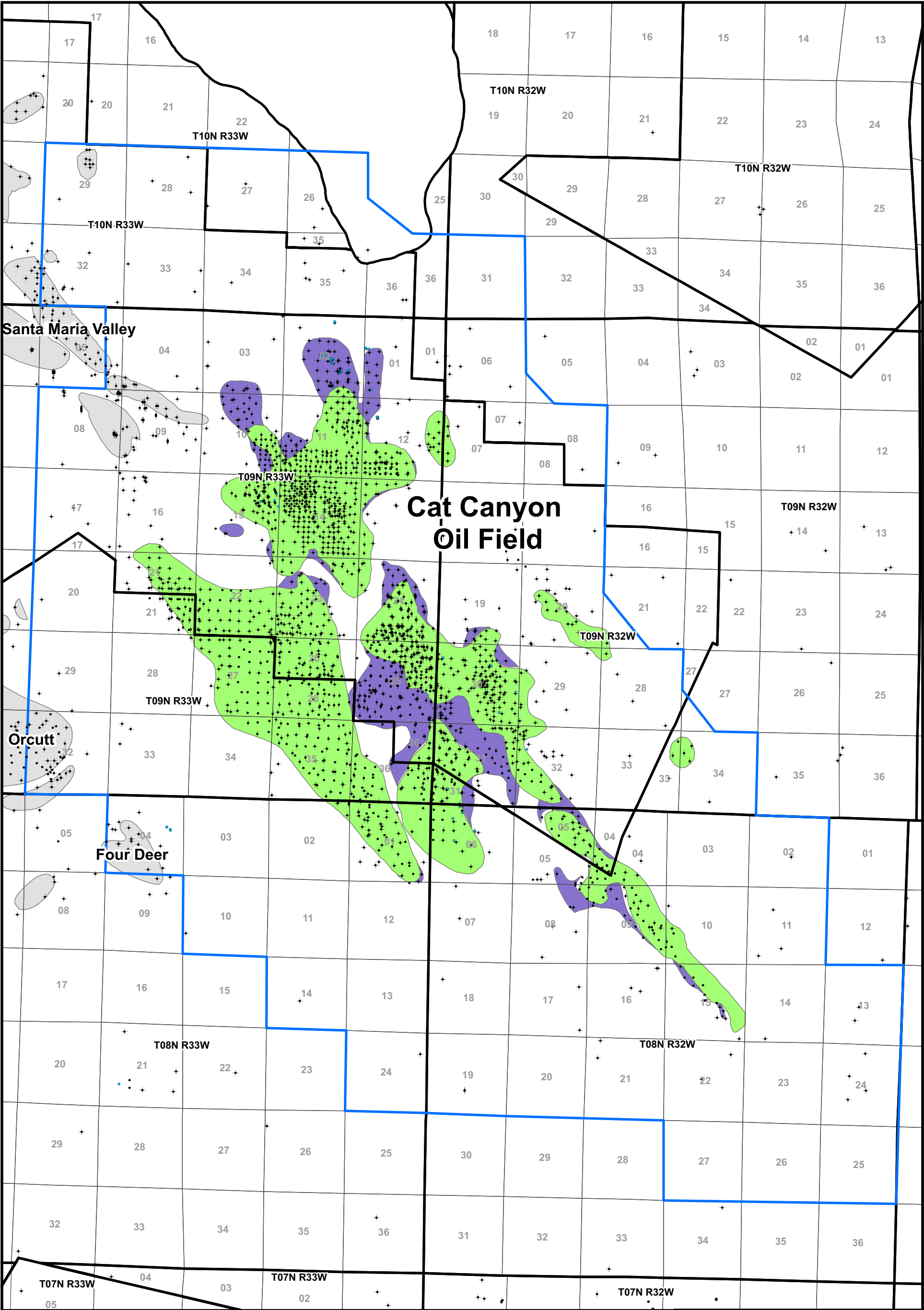


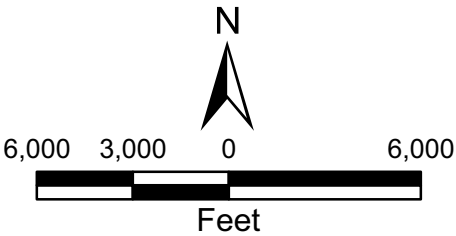
Figure 6.3-1

**Figure 6.3-2, Development Outside Current Exemption Area** shows the oil and gas development that has occurred outside the current exemption boundaries. The most recent development drilling has occurred in the northeastern area of the Cat Canyon Oil Field in the Sisquoc Area and projects are planned in the eastern area of the Eat Area of the field. The field had expanded beyond the current exemption boundaries, **Figure 6.3-2, Development Outside the Current Exemption Boundary**. In order to determine future development, a down-dip/step out well review for future commerciality was conducted.

The purpose of the Down-Dip/Step-Out Well Review is to determine, based on actual well histories, cores and logs which of the down-dip or down gradient areas had the potential to be commercially hydrocarbon productive in the future. The review was based on all the wells drilled outside the 1973 Cat Canyon Oil field productive limits.



- Legend**
- WellStatus**
- Active
  - + Buried
  - + Idle
  - New
  - + Plugged
- Study Area**
- Santa Barbara Township
  - Santa Barbara Sections
  - 1973-1974 Productive Boundary
  - Other Oilfield
  - Production Outside 1973 Production Limits



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EXEMPTION EXPANSION**

DEVELOPMENT OUTSIDE  
OF CURRENT EXEMPTION AREA

DATE: 10/17

FIGURE: 6.3-2

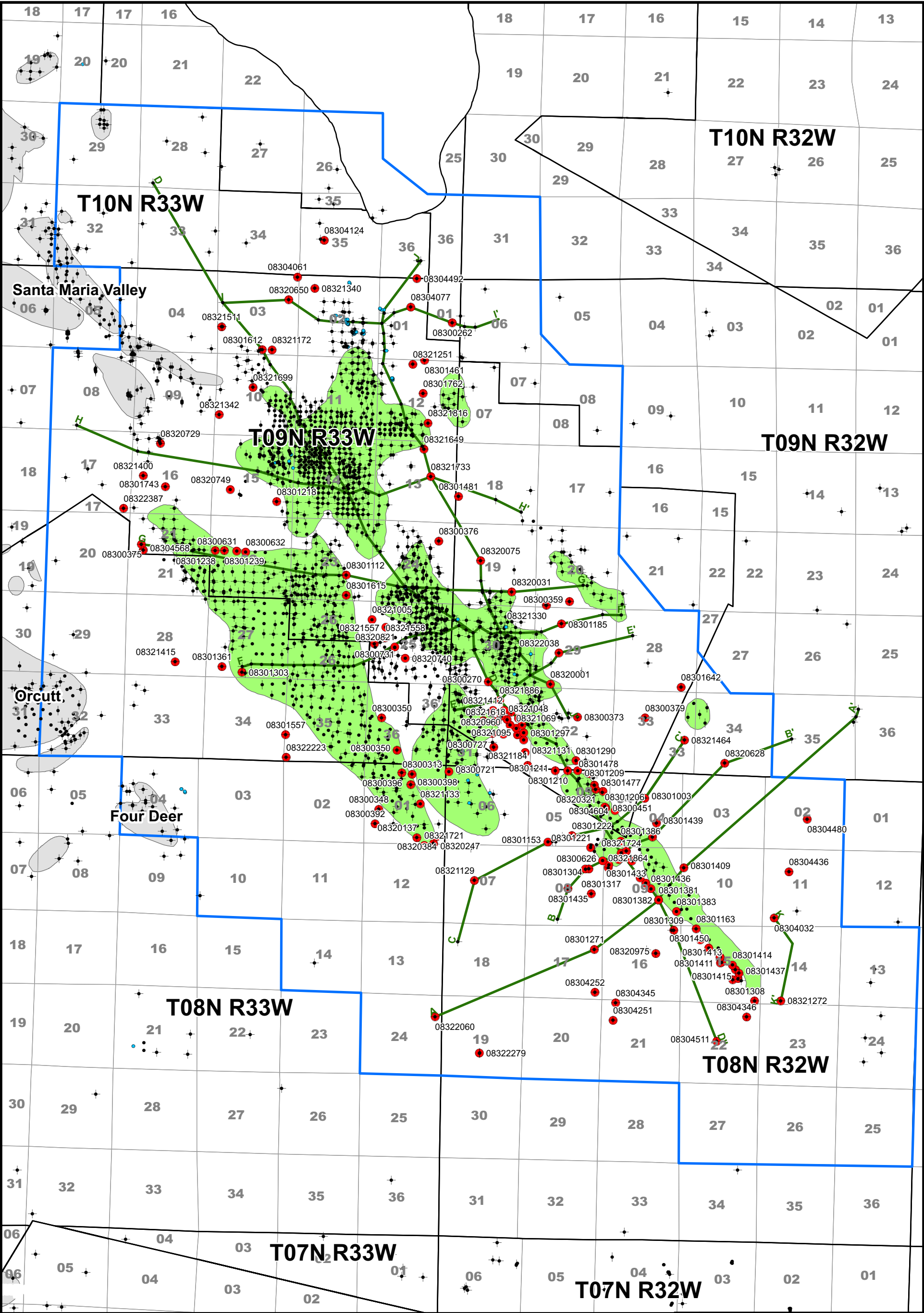
This methodology does not establish whether or not the crude oil or low level crude oil by-products such as benzene, naphthalene, or PAHs would be produced with non-oil field related water wells completed in these areas, but rather is indicative of commercial rates of hydrocarbon production now or in the future with the fluctuation of oil prices. The criteria to determine future producibility of hydrocarbons is ranked according to the level of proof provided by the well histories with actual oil production either by test or sustained production as the highest proof and log analysis as the lowest proof. The analysis flow chart is shown below in the **Figure 6.3-3, Down-Dip/Step-Out Well Review Methodology.**



Figure 6.3-3

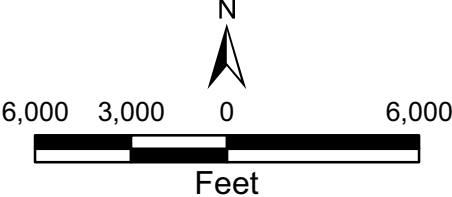
The last step in the analysis was to compare the location by zone of actual newly drilled horizontal wells in each zone, where the zones had been identified as potentially productive.


The wells to be reviewed were selected based on their location within each of the area of the fields. Every well drilled outside the 1984 exemption boundary (1973 productive limits) was reviewed. This technique is often utilized by petroleum engineering and geological professionals in evaluating acquisitions of existing fields to determine future productive areas. **Figure 6.3-4, Down-Dip/Step-Out Wells Selected** is a map of the wells selected for review showing their location in relationship to the structure of the Sisquoc, basal Sisquoc and Monterey. This is Step No. 1 of the methodology.



Legend

- WellStatus**
- Active
  - + Buried
  - + Idle
  - New
  - + Plugged
- Down Dip Wells Selected
- Cross Section
- Study Area
- 1973-1974 Productive Boundary
- Other Oilfield





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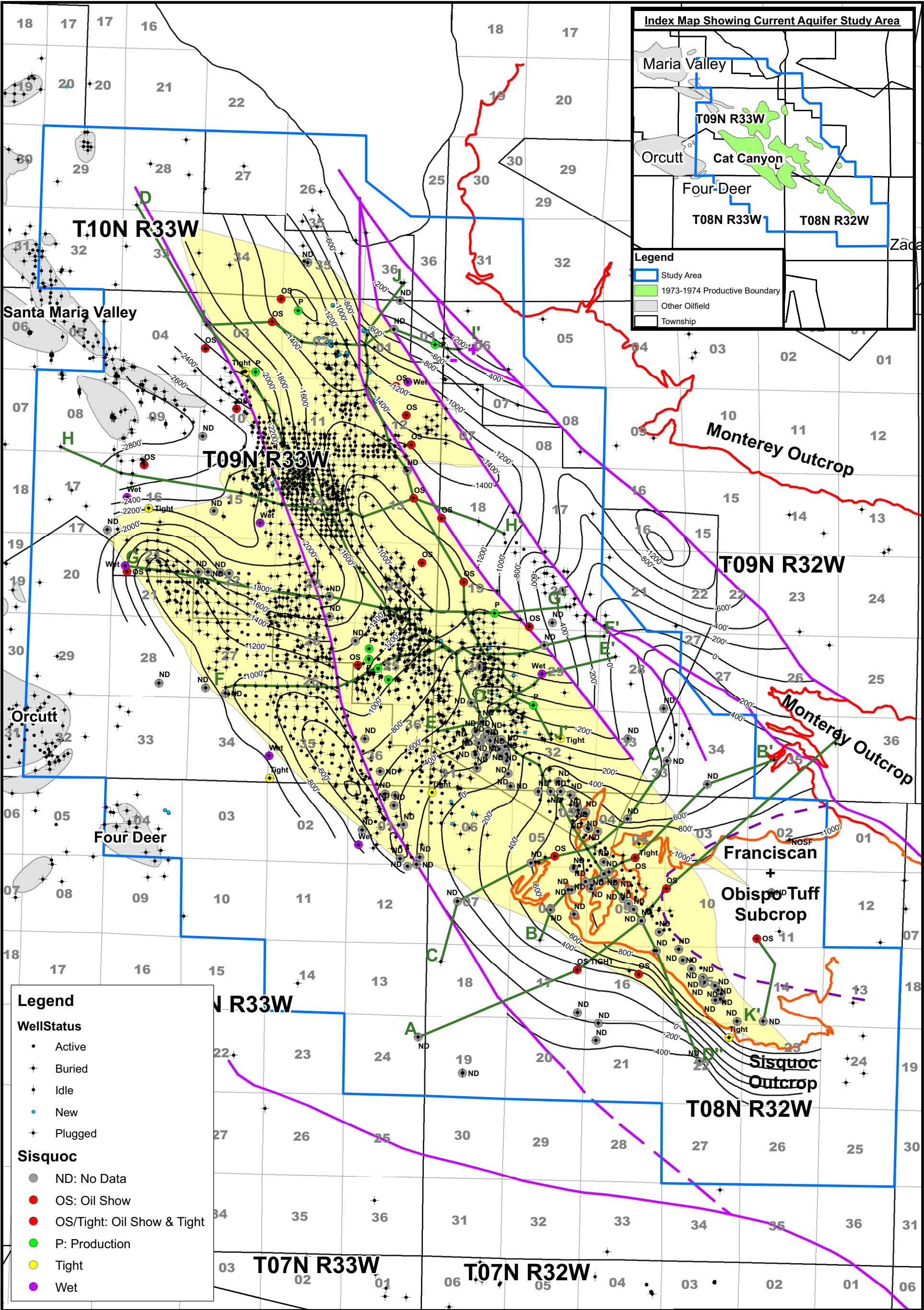
DOWN-DIP WELLS SELECTED

DATE: 10/17

FIGURE: 6.3-4

The well histories, core data, and logs were downloaded from the Division's data base- Well Finder. The information was analyzed and tabulated as Steps 2 through 5. A table of the individual well data is included in the beginning of **Appendix 6.3-II, Down-Dip Well/Step Out Review Data**. The information thus accumulated is included in **Appendix 6.3-II, Down-Dip/Step Out Well Review Data**. In Step 6, the information was plotted on the structure maps of the Sisquoc and the Monterey. In Step 7 recently drilled well information was gathered to either prove or disprove future commercial producing areas.

The results of the Down-Dip well review are shown in map form on **Figure 6.3-5, Lowest Known Oil Area in the Sisquoc** and **Figure 6.3-6, Lowest Known Oil Area in the Monterey**. The Monterey in this field is both the source rock and the producing zone in some areas. Therefore the "Lowest Known Oil Area" for the Monterey is actually the areas that have similar structural elements that provide for the natural fracturing to render the heavy crude oil producible based on the well histories, core data and logs.



**Legend**

**Fault Throw**

- Down
- Up
- Volcanic Subcrop
- Cross Sections
- Study Area
- Monterey Outcrop
- Sisquoc Outcrop

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**CAT CANYON AQUIFER  
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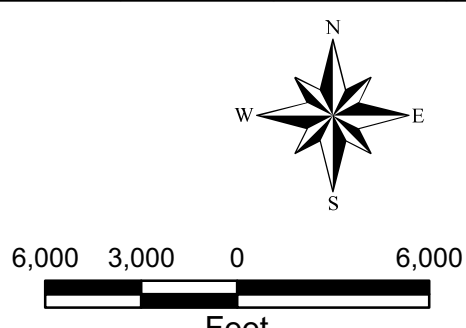
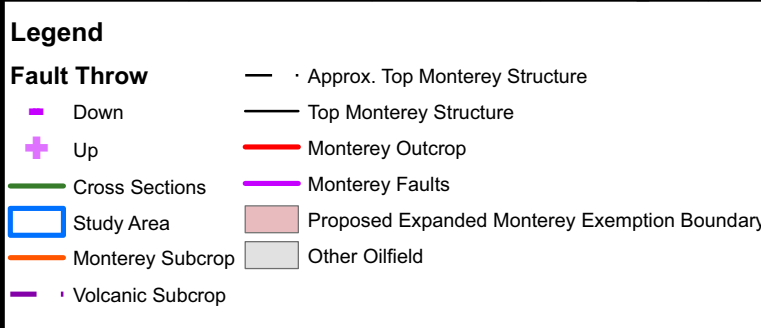
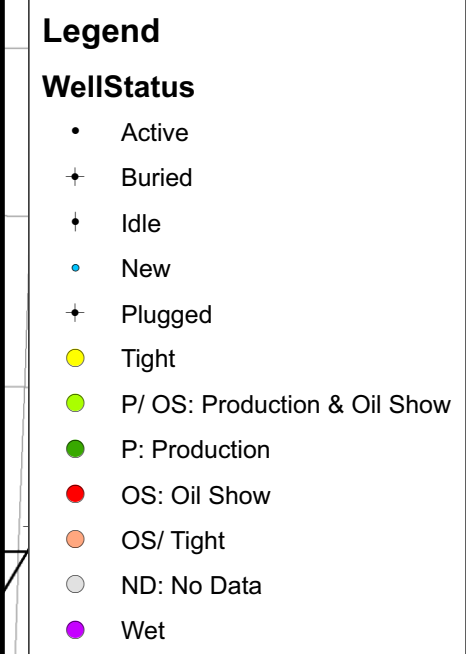
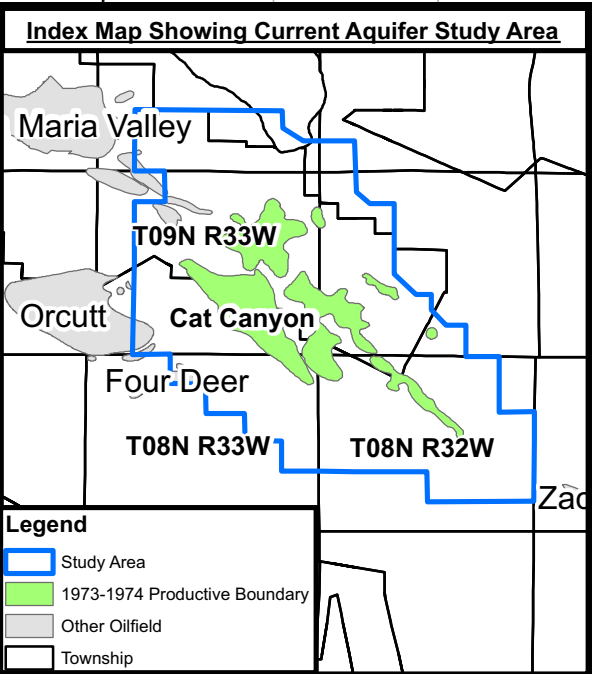
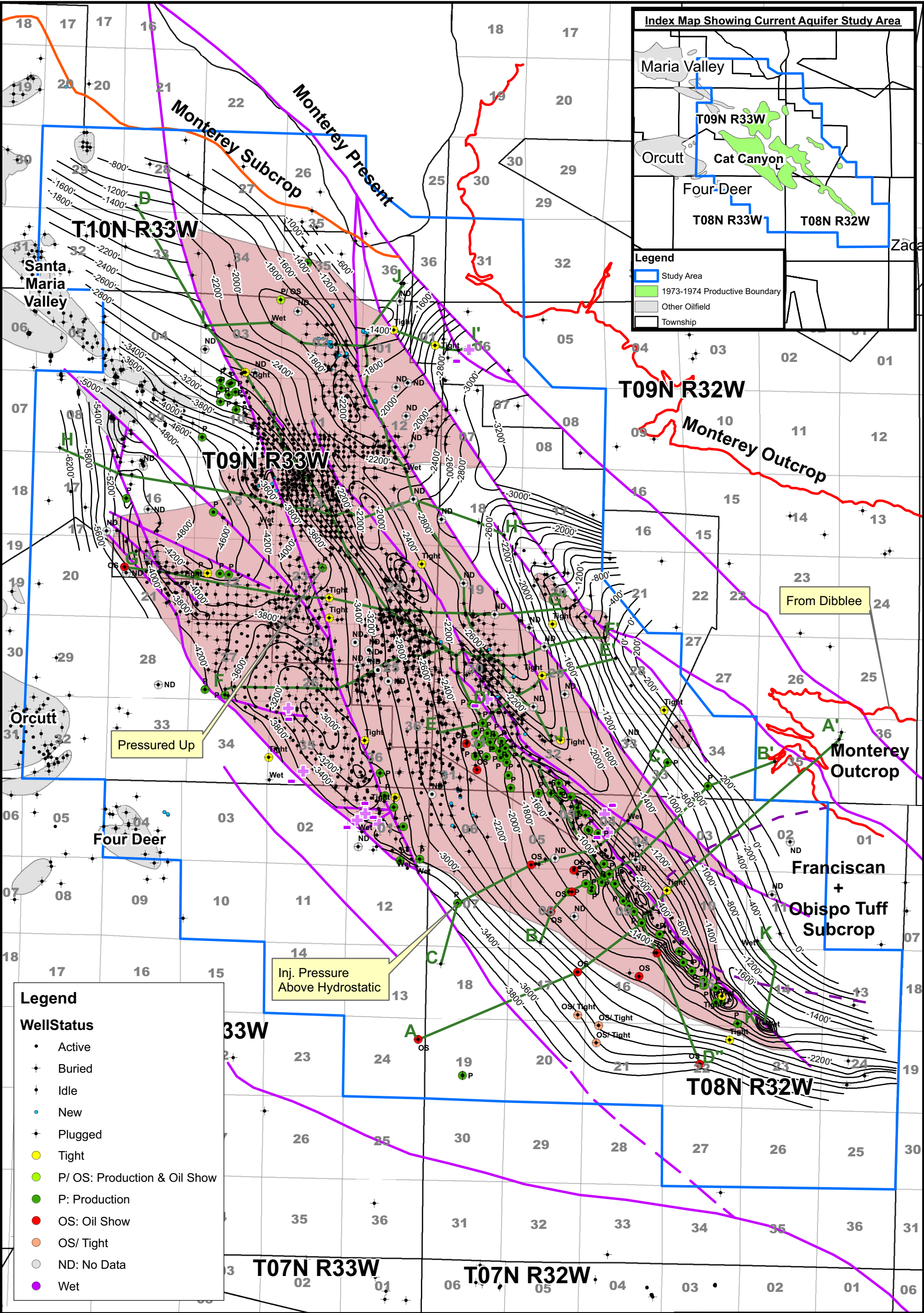
LOWEST KNOWN OIL AREA  
IN THE SISQUOC

DATE: 10/17

FIGURE: 6.3-5

**Feet**

6,000 3,000 0 6,000



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**CAT CANYON AQUIFER  
EXEMPTION EXPANSION**

**LOWEST KNOWN OIL AREA  
IN THE MONTEREY**

DATE: 10/17

FIGURE: 6.3-6

## 6.4 Injection

The water quality of the injectate and the current treatment is discussed below. Products are added to the production-to-injection cycle to facilitate production and reduce corrosion. The Material Safety Data Sheets (MSDS)s for the products was evaluated to determine the maximum possible quantity of each adjunct chemical in the product that could be realized at the point of use.<sup>16</sup> The product quantities and maximum possible component compounds were converted to mass and diluted using the production water as a surrogate for injection (assumes no field losses). **Table 6.4-1, Summary of Chemicals Added to Injectate by Water Treatment Activity in the Cat Canyon Oil Field** shows the summary of the maximum possible additives put into the oil field at various feed locations (into producing wells, separators, etc.) assuming the highest values in the ranges of product concentrations reported in MSDS. Three operators ERG, Vaquero Energy and B.E. Conway provided chemical use information. In combination these operators are responsible for 68% of the injection volume, (DOGGR, 2015).

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<sup>16</sup> Material Safety Data Sheets were provided by the applicants.  
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Table 6.4-1 Summary of Chemicals Added to Injectate by Water Treatment Activity in Cat Canyon Oil Field											
			Methanol	Ethylene Glycol	Amines	Quaternary Ammonium Compounds	Methanol	Ethylene Glycol	Amines	Quaternary Ammonium Compounds	Total Contribution to Formation by Injectate
CHEMICAL TYPE	Product Feed Gal/yr	Product Weight, lb	Maximum MSDS Percent by weight				Maximum Composition-Allocated to Injection Stream, ppm				
Conway Data (7%)											
Emulsion Breaker	273.75	2,024.93	0.60				5.98				5.98
Clarifier	273.75	2,432.93	0.15				1.80				1.80
Oxygen Scavenger	100.01	851.28	0.05		0.60	0.50	0.21		2.51	2.10	4.82
Surfactant	365.00	3,045.93		2.00		0.02		29.99		0.30	30.29
Total							7.99	29.99	2.51	2.40	42.89
ERG Data (54%)											
Asphaltene Inhib	4,197.50	32,436.06	0.00	0.00	0.10	0.00	0.00	0.00	1.11	0.00	1.11
Biocide	5,292.50	41,745.16	0.00	0.00	1.50	0.00	0.00	0.00	8.58	0.00	8.58
Chelant	730.00	7,797.57	0.00	0.00	0.38	0.00	0.00	0.00	2.03	0.00	2.03
Demulsifier	3,285.00	25,792.89	6.00	0.60	1.40	0.00	9.42	0.00	1.57	0.00	10.99
H2S Scavenger	730.00	6,542.65	0.10	0.00	0.55	0.00	0.45	0.00	2.46	0.00	2.91
Hydrate Inhib	0.00	0.00	0.70	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00
Oxygen Scavenger	2,098.75	23,468.85	0.00	0.00	0.10	0.00	0.00	0.00	1.61	0.00	1.61
Scal/Corr Inhib	273.75	2,149.66	0.15	0.00	0.00	0.15	0.22	0.00	0.00	0.22	0.44
Scale Inhib	182.50	1,433.11	0.15	0.00	0.00	0.15	0.15	0.00	0.00	0.15	0.29
Surfactant	8,942.50	73,955.06	4.50	0.00	0.00	0.00	15.19	0.00	0.00	0.00	15.19
Water Clarifier	1,095.00	10,782.57	0.10	0.00	0.00	0.30	0.37	0.00	0.00	0.00	0.37
Total							25.80	0.00	17.36	0.37	43.52
Vaquero Data (7%)											
Demulsifier	286.79	2,297.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biocide	1,182.34	9,274.62	0.00	0.00	0.90	0.00	0.00	0.00	14.43	0.00	14.43
Coagulant	464.07	4,259.94	0.00	0.00	0.00	1.20	0.00	0.00	0.00	13.25	13.25
Demulsifier	1,583.84	12,688.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2 Scavenger	6,889.38	77,039.06	0.00	0.00	0.10	0.00	0.00	0.00	39.94	0.00	39.94
Polymer	175.98	1,512.63	0.00	0.00	0.00	0.30	0.00	0.00	0.00	2.35	2.35
Surfactant	37.80	302.85	0.30	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.47
Total							0.47	0.00	54.37	15.61	70.45
Field Wide Weighted Average Contribution to Injectate, mg/L							14.52	2.10	13.35	1.46	31.44

#### **6.4.1.1 Emulsion Breaker**

Emulsion Breaker is added to the system to separate oil and water emulsions and contributes up to 11 mg/L to the injectate. Oxygen Scavenger is a corrosion inhibitor and contributes up to 39 mg/L to the injectate. Surfactant is added to the produced water to minimize scaling and plating out of contaminants and contributes up to 30 mg/L to the injectate. Clarifier is added to the system to help reduce particulates and insoluble compounds however, the MSDS indicates that the product is a mixture of inorganic salts and water and have no effect other than a deminimis effect of TDS.<sup>17</sup> The calculated effect of the compounds found in the products is simply diluted and there is no assumed reduction due to degradation, vaporization or partition. No reductions in the concentrations of the potential compounds due to conversion of solid waste or partition to oil were included. Any organic chemicals naturally found in the native crude oil produced in the Cat Canyon Oil Field were not accounted for in the injectate calculations; these organic chemicals (such as BTEX and Naphthalene) are in normal balance with the crude oil and connate water at formation conditions. The relative concentrations of these organic chemicals will be renormalized to formation conditions along partitioning coefficients to again approach native formation conditions.

#### **6.4.1.2 Well Treatment (Asphaltene Management)**

Asphaltenes (and paraffins) are solids which cover a wide range of organic materials. Asphaltene precipitation is caused by a number of factors including changes in pressure, temperature, and composition. The two most prevalent causes of asphaltene precipitation in the reservoir are decreasing pressure and mixing of oil with injected solvent in enhanced oil recovery. After precipitation, asphaltenes can remain as a suspended solid in the oil or deposit onto the rock. The asphaltene forms a solid phase of particles settling onto the rock surface. This deposition will alter wettability of the rock and cause general plugging of the formation. Aromatic compounds (BTEX) as well as other organic solvents and polymer dispersants are used to improve asphaltene solubility. Any organic chemicals naturally found in the native crude oil produced in the Cat Canyon Oil Field were not accounted for in the injectate calculations; these organic chemicals (such as BTEX and Naphthalene) are in normal balance with the crude oil and connate water at formation conditions. The relative concentrations of these organic chemicals will be renormalized to formation conditions along partitioning coefficients to again approach native formation conditions. These chemicals are used in production of the heavier crude associated with the Sisquoc Formation below the Upper Confining Layer.

#### **6.4.1.3 Produced Fluids Treatment**

Produced Fluids (consisting of oil, water and gas) are combined to allow efficient sizing of equipment. The combined streams are first sent through a gas separator designed to separate the natural gas from the water. This gas is sent to the steam facility for combustion. Oily Water leaving this system consists of 95% water and 5% oil.

Water and oil are sent to the “Free-Water Knock Out” which serves as a point of gross separation of Emulsions (consisting of 30% oil and 70% water) from Oily Water. The emulsions are sent to the wash tank for further dehydration.

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<sup>17</sup> Nalco Champion ZB-181 contains up to 10% of Aluminum Chloride and 5% of Hydrochloric Acid which in combination contribute less than 0.04 mg/L of chlorine and aluminum to the overall TDS of 6,709 mg/L.

The Waste Water from the “Skim Tank” is sent to the “Charge Tank” to be filtered with other waters prior to reuse or disposal. Oil Skims from the second “Charge Tank” are returned to the Slops Tank for re-treatment. Oil skims from the “Waste Water/Plant Feed Tank” are returned to the “Free Water Knock Out” for re-treatment.

#### **6.4.1.4 Injection Water Quality**

##### **6.4.1.4.1 Specific Treatment Chemicals Added During Treatment in Oil Production**

**Table 6.4-2, Possible Oil Production Chemicals in Injection Waters** shows product concentration range and solubility of those common chemicals that could possibly be fed as part of a treatment product into oil streams, water streams or in both-some of which are utilized by oil companies applying for the subject aquifer exemption as reported by their use records and MSDS.<sup>18</sup> **Table 6.4-2** is based on a survey of MSDS data sheets for various oilfield operations in California, including the subject leases. The chemicals represent a variety of oil and water soluble molecules including hydrocarbons, ionic species, isomers and intermediaries some of which are common named mixtures such as “Aliphatic Petroleum Distillate” or “Amine Derivatives”. Chemicals that will not partition to water in the water/oil phase are not considered to be an item of interest in the production-to-injection cycle. Water soluble compounds were grouped by pure chemical (methanol, ethylene glycol) or general functionality (amines, Quaternary Ammonium Compounds (QAC)s). Thus, “Amines” in **Table 6.4-1, Summary of Chemicals Added to Injectate by Water Treatment Activity in Cat Canyon Oil Field** may include any of the isomers or compounds below that contain an amine functional group unless otherwise treated as a QAC.

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<sup>18</sup> The values presented represent maximum plausible concentrations in any one of the numerous combinations for a given commercial product use by chemical vendors; any excess weight is made up of water or petroleum distillates depending on the solubility profile of the product components and the treated stream. The sum of any combination of the maximum concentrations in a given commercial product in Table 6.2-2 commonly exceeds 100%. The MSDS specifies a range for the specific product, again the difference is made up of water or petroleum distillates.

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Table 6.4-2 Possible Oil Production Chemicals in Injection Waters (Oil Soluble)				
	Chemical	Commercial Product Use	Percentage Reported on MSDS	Solubility
These compounds are found in injectate TPH as a function of the partitioning relative to the Crude Oil	1,2,3 Trimethylbenzene	Demulsifier	1 - 5	O
	1,2,4 Trimethylbenzene	Demulsifier	1 - 30	O
	1,3,5 Trimethylbenzene	Corrosion Inhibitor	5 - 10	O
	1,3,5 Trimethylbenzene	Demulsifier	1 - 10	O
	2-Ethylhexanol	Paraffin Dispersant	1 - 5	O
	Aliphatic Petroleum Distillate	Paraffin Dispersant	30 - 60	O
	Alkylaryl sulfonates	Paraffin Dispersant	5 - 10	O
	Cumene	Demulsifier	0.1 - 1	O
	Ethylbenzene	Demulsifier	0.1 - 5	O
	Ethylbenzene	Solvent	10- 30	O
	Heavy aromatic naptha	Demulsifier	5 - 10	O
	Kerosene	Defoamer	60 - 100	O
	Light aromatic naptha	Corrosion Inhibitor	30- 60	O
	Light aromatic naptha	Demulsifier	10 - 60	O
	Light aromatic naptha	Paraffin Dispersant	1 - 5	O
	Methanol	Solvent	60 - 100	O
	Napthalene	Defoamer	1 - 5	O
	Napthalene	Demulsifier	1 - 5	O
	Toluene	Paraffin Dispersant	31 - 60	O
	Xylene	Corrosion Inhibitor	1 - 5	O
	Xylene	Demulsifier	1 - 100	O
	Benzene	Asphaltene Solvent	1 - 5	O
	Xylene	Asphaltene Solvent	1 - 5	O
	Napthalene	Asphaltene Solvent	1 - 5	O
	Toluene	Asphaltene Solvent	1 - 5	O

Table 6.4-2 Possible Oil Production Chemicals in Injection Waters (Water Soluble)				
With the exception of Oxygen Scavenger these compounds are assumed to be found entirely in the produced water being reinjected	Diethanolamine	Cleaner	0.1 - 1	W
	Sodium hydroxide	Cleaner	0.1 - 1	W
	Sodium silicate	Cleaner	1 - 5	W
	Acid phosphate ester	Corrosion Inhibitor	0.1 - 1	W
	Amine derivatives	Corrosion Inhibitor	1 - 5	W
	Ethylene glycol/polyethylene glycol	Corrosion Inhibitor	1 - 5	W
	Fatty quarternary ammonium chloride	Corrosion Inhibitor	5 - 10	W
	Hydrogen sulfide	Corrosion Inhibitor	<0.1	W
	Isopropanol	Corrosion Inhibitor	1 - 5	W
	Methanol	Corrosion Inhibitor	5 - 30	W
	Phosphates	Corrosion Inhibitor	5 - 10	W
	Quarternary ammonium compound	Corrosion Inhibitor	1 - 10	W
	Salt of fatty acid polyamide	Corrosion Inhibitor	1 - 10	W
	Sulfur compound	Corrosion Inhibitor	1 - 5	W
	Monoethanolamine	H2S Scavenger	1 - 5	W
	Ammonium bisulfite	Oxygen Scavenger	60 - 100	W
	Nickel sulfate	Oxygen Scavenger	0.1 - 1	W
	Organic Acid	Scale Inhibitor	30 - 100	W
	Disodium ethylenediaminediacetate	Scale Inhibitor-Chelant	1 - 0.1	W
	Sodium edetate	Scale Inhibitor - Chelant	30 - 60	W
	Sodium glycolate	Scale Inhibitor - Chelant	1 - 5	W
	Sodium hydroxide	Scale Inhibitor - Chelant	1 - 0.1	W
	Trisodium nitrilotriacetic acid	Scale Inhibitor - Chelant	1 - 0.1	W
	Alkanolamine/aldehyde condensate	Scavenger	30 - 60	W
	Amine salt	Water Clarifier	5 - 10	W
	Ammonium chloride	Water Clarifier	1 - 5	W
	Ammonium chloride hydroxide	Water Clarifier	5 - 10	W
	Ammonium sulfate	Water Clarifier	10 - 30	W
	Cationic acrylamide copolymer	Water Clarifier	10 - 30	W
	Ethylene glycol	Water Clarifier	1 - 30	W
	Glycerine	Water Clarifier	1 - 5	W
	Oxylated Alkylphenol	Surfactant	20-May	W
	Salt of an organic compound	Water Clarifier	30 - 60	W
	Ethylene glycol/polyethylene glycol	Emulsion Treatment	1 - 5	W
	Benzene	Asphaltene Solvent	1 - 5	W
	Xylene	Asphaltene Solvent	1 - 5	W
	Napthalene	Asphaltene Solvent	1 - 5	W
	Toluene	Asphaltene Solvent	1 - 5	W

## 6.4.2 Description of Key Chemicals added in Processes prior to Injection

### 6.4.2.1 Methanol

Methanol is one of the largest pure component contributors to the reinjected water; it is used as a component in Corrosion Inhibitor products and can form as a decomposition product of certain other chemicals.

In the Cat Canyon Oil Field, methanol has the potential to add up to 26 mg/L to the produced water TDS ranging from 5,707 mg/L (Low Case – Sisquoc Formation below the Upper Confining Layer condensate) to 27,216 mg/L (Sisquoc Formation below the Upper Confining Layer -no condensate) and ultimately to the injectate in the produced water-to-injectate cycle, depending on the operator, area and formation. This assumes no partitioning into crude oil, which is fated to the refinery. This single carbon alcohol is a highly water soluble hydrocarbon. Methanol which is introduced into the production fluid stream will separate into both the water and crude oil phases at an approximate 3:1 ratio, (G&P Engineering Software).

Methanol is naturally occurring as a by-product of microbial digestion of more complex hydrocarbons. Formaldehyde (potentially from the decomposition of Glycols) decomposes into methanol and carbon monoxide at temperatures above 150°C, though uncatalysed decomposition is slow at temperatures below 300°C.

Methanol decomposes rapidly and is both aerobically and anaerobically digested by microbes.<sup>19</sup> The odor and taste threshold is 740,000 µg/l and the Proposition 65 Safe Harbor concentration is 12,000µg/l.<sup>20</sup>

#### 6.4.2.2 Amine Compounds

Amines (organic compounds having an NH<sub>x</sub> radical combined with alkyl groups) and complex ammonium salts including quaternary ammonium compounds (water soluble salts having an NH<sub>x</sub> radical) are the second largest contributor; they are used as a component in corrosion inhibitors and for clarification of water. Amine compounds also known as amine salts are similar to quaternary ammonium salts, amidoamines, azoles, amides as well as polyhydroxy and ethoxylated amines/amides.

In the Cat Canyon Oil Field, amine compounds have the potential to add up to 54 mg/L to the produced water TDS ranging from 5,707 mg/L (Low Case – Sisquoc Formation below the Upper Confining Layer condensate) to 27,216 mg/L (Sisquoc Formation below the Upper Confining Layer -no condensate) and ultimately to the injectate in the produced water-to-injectate cycle, depending on the operator, area and formation.

These widely varied common compounds are used in water treatment facilities as chelants or coagulants (as part of the water purification process) or to coat piping walls to prevent corrosion in piping systems, (Kelland, 2014) .

Salts of Amines and other corrosion inhibitors are used in conjunction with Quaternary Ammonium Compounds which are large molecules using nitrogen complexes with various hydrophilic/hydrophobic groups. Amine Salts should not be confused with Quaternary Ammonium Compounds (often incorrectly labeled a salt). Quaternary ammonium cations, also known as quats, are of the structure N: (R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>)<sup>+</sup>, R being an alkyl group or an aryl group. Unlike the ammonium ion (NH<sub>4</sub><sup>+</sup>) and the primary, secondary, or tertiary ammonium cations, the quaternary ammonium cations are permanently charged positive, independent of the pH of their solution and while technically a salt (as are many compounds having a strong valency) quats should be referred to as compounds.

Edetates (varying salt forms of the organic chelating agent: ethylenediaminetetra acetic acid) are used in food processing, liquid soaps, oil emulsifiers, pharmaceuticals, (Hawley, 1981).

Products sold to operators commonly contain edetates as a chelant.

These chemicals decompose into component parts such as smaller amine complexes, ammonia, nitrogen and CO<sub>2</sub>.

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<sup>19</sup> OEHHA, Technical Support Document: Toxicology Clandestine Drug Labs/ Methamphetamine  
Volume 1, Number 10, METHANOL

Methanol readily biodegrades in water with a half-life between one and ten days. Volatilization half-lives for a model river (1m deep) and an environmental pond have been estimated at 4.8 days and 51.7 days, respectively. Volatilization from surface waters may be significant based upon Henry's Law constant.

<sup>20</sup> SWQCB

### 6.4.2.3 Quaternary Ammonium Compounds

Quaternary Ammonium Compounds (QAC)s provide both surfactant and film-forming capabilities and serve as clarifiers and corrosion inhibitors and due to their toxicity some specific quaternary salts are used as biocides in oil wells.

In the Cat Canyon Oil Field, Quaternary Ammonium Compounds have the potential to add up to 15 mg/L to the produced water TDS ranging from 5,707 mg/L (Low Case – Sisquoc Formation below the Upper Confining Layer condensate) to 27,216 mg/L (Sisquoc Formation below the Upper Confining Layer -no condensate) and ultimately to the injectate in the produced water-to-injectate cycle, depending on the operator, area and formation.

Quaternary ammonium compounds (QAC) are organic molecules that are extensively used in domestic, agricultural, healthcare, and industrial applications as surfactants, emulsifiers, fabric softeners, disinfectants, pesticides, corrosion inhibitors, and personal care products.

Quaternary salts thermally decompose at temperatures above 180 degrees C. MCLs or Prop 65 Safe Harbor limit have not been established for Quaternary Salts.

QACs are used in agricultural formulations as biocides and surfactant (to enhance the solubility, rain fastness and penetration) of pesticides as they are applied together with the pesticides.

QACs are used in the production of organoclays used in a number of different formulations such as oil-based drilling fluids, printing inks, oil based paints, latex polymers and nail polishers.

Organoclays are able to adsorb organic molecules from both aqueous systems and air and are used in landfill liners, groundwater remediation and in air filters. Oil-field applications of QACs include anti-swelling/clay stabilization, foaming, silt suspension, corrosion inhibition, biocides and demulsification, (Tenzel, 2009).

Quaternary ammonium compounds are organic compounds that contain four functional groups attached covalently to a central nitrogen atom ((R)<sub>4</sub>N)<sup>+</sup>. These functional groups (R) include at least one long chain alkyl group and the rest are either methyl or benzyl groups. QACs are large molecules having molecular weights typically between 300 and 400 g/mole and are composed of two distinctly different moieties: hydrophobic alkyl groups and a hydrophilic, positively charged central N atom, which retains its cationic character at all pH values, (Kelland, 2014).

While QACs are toxic to aquatic organisms at environmentally relevant concentrations, they are also biodegradable in biological systems such as activated sludge systems, surface waters, soil and groundwater under aerobic conditions. The half-lives of aerobic degradation of QACs in such systems vary extensively from hours to months depending on the QAC concentration and structure, microbial acclimation and presence of QAC resistant/degrading microorganisms, (Tenzel, 2009).

However, the more critical mitigation in terms of QAC potential groundwater impacts is the nature of the QAC in terms of its adsorption. QACs are used in oil and gas production as a Film Forming Corrosion Inhibitor (FFCI). These compounds are used to prevent various forms of corrosion due to the presence of chloride, CO<sub>2</sub>, and H<sub>2</sub>S in produced streams. The mechanism for the use of FFCI as a corrosion inhibitor is adsorption onto surfaces exposed to the solution being transported or contained and the resistance to water intrusion once secured to the substrate as a film. In the common practice of injection of produced water whatever QACs are injected will most likely find a suitable substrate to adsorb to and remain in the formation until

decomposition is complete. In the unlikely event that the QACs were returned to the surface they would be filtered out or removed in softener sludge.

#### **6.4.2.4 Azoles**

An azole is a five-member nitrogen heterocyclic ring compound containing at least one other non-carbon atom of nitrogen, sulfur, or oxygen. The parent compounds have a stable ring structure and two double bonds. Commonly found in nature, imidazole and other six-member cyclic molecules containing two nitrogens are important building blocks in biochemistry. Due to the presence of the nitrogen molecules azoles are similar to amines in decomposition fate.

#### **6.4.2.5 Polyacrylates**

One of the largest uses for polyacrylamide is to flocculate solids in a liquid. Polyacrylamide can be supplied in a powder or liquid form, with the liquid form being subcategorized as solution and emulsion polymer. The adjunct contribution of amines is conservatively considered to be the same as Amines.

Even though these products are often called ‘polyacrylamide’ with water, many are actually copolymers of acrylamide and one or more other chemical species, such as an acrylic acid or a salt thereof. The main consequence of this is to give the polyacrylamide with water wells polymer a particular ionic character and it is often used as a defoamer. These defoamers are often delivered in a solvent carrier like petroleum distillates. Another common use of polyacrylamide and its derivatives is in subsurface applications such as Enhanced Oil Recovery. High viscosity aqueous solutions can be generated with low concentrations of polyacrylamide polymers, and these can be injected to improve the economics of conventional water flooding.

In the Enhanced Oil Recovery operations, polyacrylamide polymers are susceptible to chemical, thermal, and mechanical degradation resulting in the evolution of ammonia as well as a free carboxyl group. Thermal degradation of the vinyl backbone can occur through several possible radical mechanisms, including the autoxidation of small amounts of iron and reactions between oxygen and residual impurities from polymerization at elevated temperature. Mechanical degradation can also be an issue at the high shear rates experienced in the near-wellbore region. However, cross-linked variants of polyacrylamide have shown greater resistance to all of these methods of degradation, and have proved much more stable.

#### **6.4.2.6 Ethylene Glycol**

Ethylene Glycol is used as a component in Corrosion Inhibitors and in Water Clarifiers. In the Cat Canyon Oil Field, Ethylene Glycol has the potential to add up to 30 mg/L to the produced water TDS ranging from 5,707 mg/L (Low Case – Sisquoc Formation below the Upper Confining Layer condensate) to 27,216 mg/L (Sisquoc Formation below the Upper Confining Layer -no condensate) and ultimately to the injectate in the produced water-to-injectate cycle, depending on the operator, area and formation. Ethylene Glycol is used as a component of common automotive coolant, paints, fabric and cosmetics. Ethylene Glycol decomposes to form: glycolic, oxalic, and formic acids.

#### **6.4.2.7 Inorganics**

Salts are compounds derived from the combination of an alkali and an acid; it consists of the cation of the alkali and the anion of the acid. These combinations of metals and non-metals

(mostly halogens) herein referred to as inorganic salts are the dissolved mineral components but exclude any molecules containing Carbon, plus Hydrogen, Oxygen, Sulfur and Nitrogen but not exclusively. They comprise the majority of the dissolved solids in oil field and steam plant water as well as the resultant injection water. These mineral-related elements can be added to achieve desired chemical buffering, reactions or to enhance other chemical performance.

All other water soluble chemicals introduced in the chemical treatment of water are small quantities (0.01 – 1 % in the product container) or are salts similar to the native geochemistry, and the product volume is simply water used to hold the other product compounds in manageable solutions for shipment, delivery and as a vehicle for injection into the various process locations.

### 6.4.3 Current Beneficial Uses

Currently, there are no drinking water wells producing from the confined Monterey Formation and Sisquoc Formation below the Upper Confining Layer which are the subject of this proposed Aquifer Exemption Expansion Application Study. Some oilfield operators are using source water wells for Thermally Enhanced Oil Recovery (TEOR) projects. Once-Through-Boilers are producing 60% to 80% quality steam and due to their tolerance for high TDS water, the softened feed water to these boilers can have TDS values as high as 6,000 mg/L. Thus obviating the need to use low TDS sources for water. These source wells are in producing formations having lower Total Dissolved Solids, see Section 5.1, Hydrogeologic Setting and the Formation Water Analysis and Data, Appendix 5-IV. Other than possibly serving to dilute the near SC well bore TDS, the injection of steam or water does not impact the overall Monterey Formation and Sisquoc Formation below the Upper Confining Layer water quality in any specific area.

## 7 Exemption Description

While the maps and cross sections delineate the geologic formation boundaries, the legal description of the expansion follows the fault block on the top of the respective intervals which delineates the proposed aquifer exemption expansion boundary. The proposed exemption expansion area extends beyond the California Administrative Boundaries of Cat Canyon Oil Field. The area is delineated by map and cross section. The proposed Aquifer Exemption Expansion boundary for Sisquoc Formation below the Upper Confining Layer, and Monterey Formation in the Cat Canyon Oil Fields is described as follows:

T8N, R32W- Sections: 03, 04, 05, 06, 07, 08, 09, 10, 14, 15, 16, 22, and 23

T8N, R33W-Sections: 01, 02, and 12

T9N, R32W- Sections: 07, 18, 19, 20, 29, 30, 31, 32, and 33

T9N, R33W- Sections: 01, 02, 03, 04, 10, 11, 12, 13, 14, 15, 16, 21, 22, 23, 24, 25, 26, 27, 28, 34, 35, and 36

T10N, R33W- Sections: 33, 34, and 35

A set of GIS files are included as **Appendix 7-I, Proposed Aquifer Exemption Boundaries.**

## 8 Justification for the Aquifer Exemption

### 8.1.1 Sisquoc Formation below the Upper Confining Layer and Monterey Formation

#### 8.1.2 CFR 146.4

An aquifer may be exempted as a potential USDW by the Division if:

#### 8.1.2.1 Requirement:

*“a) It does not currently serve as a source of drinking water; and*

##### 8.1.2.1.1 Response to Requirement

The Sisquoc Formation below the Upper Confining Layer, and the Monterey Formation do not currently serve as a source of drinking water as shown by map and cross sections: **Figure 5.1-3, Water Well Location Map** and **Figure 5.1-4, Cross Section A-A’ with water wells**; **Figure 5.1-5, Cross Section B-B’ with water wells**; **Figure 5.1-6, Cross Section C-C’ with water wells**; **Figure 5.1-7a, Cross Section D-D’ with water wells**; **Figure 5.1-7b, Cross Section D’-D’’ with water wells**, **Figure 5.1-8, Cross Section E-E’ with water wells**; **Figure 5.1-9, Cross Section F-F’ with water wells**; **Figure 5.1-10, Cross Section J-J’ with water wells**; **Figure 5.1-11, and Cross Section K-K’ with water wells**. The water well inventory was compiled based on data from Santa Barbara County, Geo-tracker, Department of Water Resources Water Quality Library, Department of Water Resources water well files, USGS publication, and a field inspection conducted by operators and contract employees.

#### 8.1.2.2 Requirement

*b) It cannot now and will not serve as a source of drinking water because:*

*(#1) It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class II or III operation to contain minerals or hydrocarbons that considering their quantity and location are expected to be commercially producible.*

##### 8.1.2.2.1 Response to Requirement

The Sisquoc Formation below the Upper Confining Layer, and Monterey Formation has been shown from core descriptions and production to be hydrocarbon bearing. The well-established recovery mechanism for increased recovery through water flooding, steam injection both cyclic and flood will continue to be used to further develop the subject area.

#### 8.1.2.3 Requirement

*b) It cannot now and will not serve as a source of drinking water because:*

*(#2) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical;*

*(#3) It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; or*

##### 8.1.2.3.1 Response to Requirement

The subject waters have Total Dissolved Solids that are too high to meet the MCLs established for safe drinking water without substantial treatment, **Appendix 6-I, Table 7.1-2, Summary for the Sisquoc Formation below the Upper Confining Layer, and Monterey Formation Average Water Composition by Section, Township and Range, with MCLs**. The costs identified in **Table 8.1-1, Economic Feasibility Summary-to Treat the Cat Canyon Oil Field Sisquoc Formation below the Upper Confining Layer, and Monterey Formation Water to**

**Drinking Water Quality** shows the costs associated with such treatment assuming the field could produce enough water to serve the entire Los Alamos CDP, Sisquoc CDP and Garey CDP.

Table 8.1-1: Economic Feasibility Summary-to Treat Formation Water for Residential Use											
	Per Household Rate Burden (Annualized \$/HH)					Income Burden		Increment Sensitivity			Subsidy
	Wells	Facilities	Piping	Operational	Total	Santa Barbara County	Los Alamos CSD	Threshold Increase	Current Water Source Rate (L/ACSD)	Current Water Source Rate (GSWC)	AB2334 High Cost Subsidy Eligibility
Economic Base						\$89,903	\$83,499	\$450	\$460	\$617	\$83,499
Low Case 2000 feet (Average Well Depth)											
1799 Household Case	\$311.00	\$1,456.31	\$122.35	\$5,074.15	\$6,963.81	8%	8%	15.48	\$16.14	12.29	8%
Sisquoc Formation below the Upper Confining Layer 2000 feet (Average Well Depth)											
1799 Household Case	\$311.00	\$1,905.93	\$122.35	\$6,528.98	\$8,868.26	10%	11%	19.71	20.28	15.37	10%
Monterey Formation 3000 feet (Average Well Depth)											
1799 Household Case	\$466.50	\$1,464.40	\$122.35	\$5,326.28	\$7,379.53	8%	9%	16.40	17.04	12.96	8%

For residential consideration-

The composition of the subject waters requires over 8% of the annual income of the households in Los Alamos CDP, Sisquoc CDP and Garey CDP. A reasonable threshold for willingness-to-pay has been established by EPA as 0.04% of the household income, **Appendix 6-1, Treatment Feasibility Study, Tables 1.2-2 and 7.1-2.**

Local costs may be substantially higher if the service provider is not able to obtain permits to inject waste from the treatment of the subject waters. Also, given that The Division drilling requirements are presently required to for safety, the water service provider would also be expected to use future yet to be defined regulatory approved safety and environmental measures.

For agricultural consideration-

The subject waters contain Boron concentrations that are over one magnitude greater than the acceptable limits for Boron in irrigation water, **Appendix 6-1, Treatment Feasibility Study.** Boron remains the largest problem for use as an agricultural source. The cost for a farmer to produce and treat the least costly source East Area water to a suitable level of boron (with no Service or Distribution costs) is substantially greater (150 times costlier) than the current all-in cost of \$40/ac-ft for water deliveries at the farm well head with current supplies of low boron water. (Gibbs, 2012). The levelized cost to drill a deeper and compliant oil field well penetrating

a hydrocarbon producing formation is roughly 5 times greater (928 \$/Mgal vs 130 \$/Mgal) all other costs are additive in the comparison between the normal agricultural groundwater supply (Alluvium, Paso Robles, Careaga and Foxen) and the deeper oil producing zone supply from the Sisquoc Formation below the Upper Confining Layer and Monterey Formation.

Table 8.1-2: Economic Feasibility Summary-to Treat Formation Water for Agricultural Use						
	Per Household Rate Burden (Annualized \$/HH)					
	Wells	Facilities	Piping	Operational	Total	Agricultural Water
Economic Base						\$40/ac-ft (\$130.32/Mgal)
Low Case 2000 feet (Average Well Depth)						
Cost to serve ag water (\$/Mgal)	\$928.46	\$4,347.73	\$365.27	\$18,065.14	\$23,706.61	181.91
Sisquoc Formation below the Upper Confining Layer 2000 feet (Average Well Depth)						
Cost to serve ag water (\$/Mgal)	\$928.46	\$5,690.03	\$365.27	\$22,408.47	\$29,392.23	225.54
Monterey Formation 3000 feet (Average Well Depth)						
Cost to serve ag water (\$/Mgal)	\$1,392.69	\$4,371.87	\$365.27	\$20,194.43	\$26,324.26	202.00

No economic consideration was included for the economic burden associated with split estate management of the hydrocarbons that would be produced with any water, **Appendix 6-I, Treatment Feasibility Study.**

#### 8.1.2.4 Requirements:

- b) It cannot now and will not serve as a source of drinking water because:*
- (#4) It is located over a Class III well mining area subject to subsidence or catastrophic collapse; or*

##### 8.1.2.4.1 Response to Requirement

Not applicable.

#### 8.1.2.5 Requirements:

- c) The total dissolved solids content of the ground water is more than 3,000 mg/l and less than 10,000 TDS mg/l and it is not reasonably expected to supply a public water system."*

##### 8.1.2.5.1 Response to Requirement

In the context of the percentage of per Household Income: The case having the lowest cost to a household is the facility design using the best economy of scale (as if serving 1,799 households) applied to the production of water to serve the entire 1799 households as consumers at the local per capita rate. Los Alamos CSP only serves approximately 500 households whereas the Golden

State Water Company which extends service to Sisquoc CDP serves a larger population of Households but sets individual rates for the regional service under CPUC oversight.

The Total Dissolved Solids concentration of the subject waters range from 7,668 mg/L in East Area Sisquoc Formation below the Upper Confining Layer to 22,231 mg/L in Sisquoc Area Sisquoc Formation below the Upper Confining Layer; Condensate is returned to the surface during the production cycle at an average TDS of 5,707 mg/L, Treatment requires over 8% of the annual income of the households in the Los Alamos CDP, Sisquoc CDP and Garey CDP. A reasonable threshold for willingness-to-pay has been established by EPA as 0.04% of the household income.

Even under the most optimistic circumstances there are no cases where the Cat Canyon Sisquoc Formation below the Upper Confining Layer or Monterey Formation waters can be produced, treated and delivered in a cost effective manner. In fact, for the lowest cost case, assuming condensate was present in sufficient quantities near the location of the new well (Low TDS Case), the all-in cost to the households would be 12 to 16 times the incremental threshold established by EPA. The water would also exceed the 2% income threshold established by the State under AB2334, thus requiring state subsidies.

Costs may be substantially higher if the service provider is not able to obtain permits to inject waste from the treatment of the subject waters. Also, given that the Division's drilling requirements are presently required for safety, the water service provider would also be expected to use future, yet to be defined, regulatory approved safety and environmental measures.

### **8.1.3 PRC 3131(a)**

An aquifer may be exempted as a potential USDW by the Division if:

#### **8.1.3.1 Requirement**

*"#1) It meets the criteria set forth in Section 146.4 of Title 40 of the Code of Federal Regulations.*

#### **8.1.3.2 Response to Requirement**

The Sisquoc Formation below the Upper Confining Layer and Monterey Formation sands meet the criteria set forth in Section 146.4 (a) and (b)(1) of Title 40 of the Code of Federal regulations.

#### **8.1.3.3 Requirement**

*#2) The injection of fluids will not affect the quality of water that is, or may reasonably be, used for any beneficial use.*

##### **8.1.3.3.1 Response to Requirement**

Due to the hydrocarbon bearing nature of the fluids contained in the Sisquoc Formation below the Upper Confining Layer and Monterey Formation, and the confinement of the sands geologically, the injection of produced water for enhanced recovery will not affect the quality of water that is, or may reasonably be used for any beneficial use. The beneficial use will not be impacted by the enhanced recovery. The formation volume is defined by the area and depth of the confined formations and the injectate is the produced water that is separated from the oil and returned. The small amounts of treatment chemicals (in some instances similar hydrocarbons to those produced)

will repartition into the remaining oil in the formation, decompose or be diluted in the formation water to levels of insignificance; the inorganic salts and free anionic and cationic ions from organic compounds (which are similar to the native geochemistry) will be diluted to insignificance, **Section 6.3 Description of Key Chemicals added in Processes prior to Injection.**

#### **8.1.3.4 Requirement**

*#3) The injected fluid will remain in the aquifer or portion of the aquifer that would be exempted.”[ed.]*

##### **8.1.3.4.1 Response to Requirement**

The confinement geologically of the Sisquoc Formation below the Upper Confining Layer, and Monterey Formation sands by the Upper Sisquoc Confining Layer and the Foxen clay above and the Basal Sisquoc clay and Point Sal shale below coupled with sealing faults forming permeability barriers for areal confinement and the hydraulic gradient of the depleted areas ensures that the injected water will remain in the Proposed Exemption Area of the Sisquoc Formation below the Upper Confining Layer and the Monterey Formation.

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